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Investigating the Impact of Game-Based Learning in Mathematics Using Tablets Among Primary School Students

Farzana Hayat Ahmad, Muddassir Malik, Salma Siddiqui, and Hira Khan

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Design
Kriselle de Leon

Layout
Patrick Jacob Liwag

Cover photo
Sadaf Munir

TABLES

FIGURES

ACRONYMS

AET	active engaged time
ARCS	attention, relevance, confidence, and satisfaction
BOSS	Behavioral Observation of Students in School
DGBL	digital game-based learning
EGRA	Early Grade Reading Assessment
FGD	focus group discussion
HT	head teacher
ICT	information and communications technology
IMMS	Instructional Material Motivational Survey
ITE	innovative technologies in education
ITL	innovative technologies in learning
M&E	monitoring and evaluation
NUST	National University of Sciences and Technology
OFT-M	off task motor
OFT-P	off task passive
OFT-V	off task verbal
OSC	out-of-school children
OSCS	out-of-school children school
PET	passive engaged time
SD	standard deviation
TMS	Total Motivation Score

CONTENTS

ABSTRACT

The study seeks to investigate the impact of digital game-based learning (DGBL) using technology in low-cost tablets installed with instructionally sound educational games, which may help in disrupting the current education system and give access to meaningful learning to all. Recent research on mobile learning corroborates the extension of educational experiences beyond the classroom and enables informal and personalized learning for students. The key focus areas of this study are the use of digital games in enhancing students' achievement, motivation, and engagement by providing a self-paced learning concept with minimum teacher intervention. A mixed-method quasi experiment study was conducted among 200 children living and working on the streets, belonging to an extremely low-income group, and formally enrolled in charity schools for out-of-school children in Pakistan. An experiment group was exposed to DGBL, and a control group was taught using traditional methods of instruction. The study generated significant results in engagement and achievement data with a large effect size. Motivational data seem to be statistically insignificant. However, the study revealed consistently higher motivation among students learning through digital games, compared with those taught using traditional methods. The study results may be generalized to a large scale provided that digital game-based content is developed considering the social and cultural context of the target population.

Keywords: *digital game-based learning, self-paced learning, tablet technology, instructional designing, out-of-school children, personalized learning*

I. INTRODUCTION

Pakistan has always struggled with developing a coherent formal education system. The books published by the various educational boards in Pakistan do not comply with world quality standards for pedagogy and instructional design; they fail to deliver concepts and focus on memorization and rote learning (Mahmood, 2010). Moreover, the examination-based assessment system demands that students reproduce what they have memorized during the lessons, which eventually influences the classroom pedagogies to prioritize rote learning. This approach to teaching and learning is in contrast with constructivist learning theories that propose active engagement of students with the learning content so they will construct their own knowledge by integrating newly acquired concepts and procedures into existing mental structures. Hence, the existing approach of rote memorization in Pakistan's educational model ultimately leads to lack of interest in learning, resulting in potential school dropouts.

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Pakistan is the only non-African country that has the highest shortfall of teachers on the list of countries in the Education for All Global Monitoring Report (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2014). It is among 21 countries facing an "extensive" learning crisis, based on a number of indices, such as enrolment, dropout rates, academic performance, and literacy (Global Education Monitoring Report, 2016). Pakistan scores low in every index. Besides the need to revise the curriculum content of the public education system, a huge percentage of the population has no opportunity to go to school.

Pakistan has 22.6 million out-of-school children (OSC) between the ages of 5 and 16 (Academy of Educational Planning and Management, 2017). This number declined by 3% over the last two years (ASER, 2017), but still paints a gloomy picture that calls for an imposition of education emergency in the country. In such circumstances, it is imperative, therefore, to introduce accelerated learning programs for out-of-school children and encourage non-formal and flexible learning aimed at improving education quality and accessibility. According to recent research, one way to achieve accessibility of quality education is to introduce game-based learning using mobile technology such as low-cost tablets installed with instructionally sound educational games or applications, which may help in disrupting the current education system and provide access to meaningful learning to all (Ally, Balaji, Abdelbaki, & Cheng, 2017). Recent research on mobile learning also corroborates the extension of educational experiences beyond the classroom, finding that mobile learning enables informal and personalized learning for students (Ryan, 2016).

Hence, to address the issue of quality education, access, and efficiency, this study sought to explore the impact of digital game-based learning (DGBL) in tablets as it relates to access and quality education for primary school children from low socioeconomic backgrounds.

II. OBJECTIVES

Alongside government initiatives, the civil sector in Pakistan has played a major part in enrolling out-of-school children, who either cannot afford basic education or have exceeded the enrolling age in mainstream schools. This study focused mainly on children living and working on the streets who were enrolled in out-of-school children schools (OSCSs).

The study had the following objectives:

- To create a knowledge base and stimulate debate at national and international levels
- To address the issues of equity, quality, and efficiency at the primary education level using game-based learning delivered through tablet technology
- To demonstrate interactive, individualized, and customized learning for each learner of both genders belonging to various socioeconomic backgrounds.

Research Questions

To achieve the aforementioned objectives, this study examined the effectiveness of a game-based tablet application on the topic of Measurements derived from the National Curriculum of Primary School Mathematics and compared it against traditional classroom pedagogies.

Data collection was informed by the following research questions:

- Does game-based learning in mathematics, using tablets, result in increased engagement, motivation, and academic achievement among primary school students of a low socioeconomic background?
- To what extent is it possible to practice self-paced learning in mathematics through a tablet-based app without the need of an instructor for the student?
- Do teachers find game-based learning using tablets an acceptable treatment for use in the classroom compared to traditional techniques for learning mathematics?

III. REVIEW OF LITERATURE

This section presents an overview of the pertinent literature related to the use of digital game-based learning in transforming education to achieve quality, equity, and efficiency. It will start by presenting a broader view of DGBL and then explore the impact of DGBL on student achievement, engagement, and motivation. It will review literature on the efficiency and equity achieved by learning through digital games.

3.1 Digital Game-Based Learning

DGBL is broadly defined as a form of learning that elicits experiential engagement of players in a learning activity using technological tools, such as computers, tablets, smartphones, net books, etc. (Kiili, 2005). Learners are placed in a virtual environment of the “game play” that presents topics and ideas as rules, decisions, and consequences instead of content to be communicated or assimilated (Perrotta, 2013; Teed, 2012).

In curricular context, this means translating an element of a subject (e.g., laws of motion) into game mechanics, which operates according to the rules defined by game logic. Such games need to be engaging, although not always necessarily fun in playing, while learning could be implicit or explicit (Ulicsak & Wright, 2010). There may be no uniform pedagogy for serious educational games, with earlier games mostly based on a behaviorist approach to learning, whereas later games incorporated experiential, situated, and socio-constructivist learning theories (Kim, Park & Baek, 2009). However, achievement of desired learning outcomes depends upon pedagogically informed instruction designing, underlying game mechanics, internal logic, and how the content is integrated into the game to make learning intrinsic to play. While game-based learning is considered to spark engagement by introducing a fun element into learning and interaction with the subject content, it is crucial to make an informed selection of games that are user-friendly and keep learners challenged and motivated to achieve desired learning outcomes (Chiu, Kao & Reynolds, 2012; Teed, 2012). In a nutshell, DGBL offers ways for students or players to fully engage with the content and learn through interaction and simulation, rather than conventional schooling, textbooks, assignments, and so forth.

3.2 Impact of Digital Games on Quality Education

The United Nations Children’s Fund (2017) lists five factors of education quality: learners’ prior experience, learning environment, learning content, learning process, and learning outcomes. High-quality education supports holistic student development by connecting academic and interpersonal learning with real-world experience. Play is also an important element of healthy child development (Ginsburg, 2007) and learning development. Young children are highly imaginative compared with adults and thus learn better through imaginative play (Bardon & Josserand, 2009; Peirce, 2013). Digital technology has enabled the creation of games that relate to real-world scenarios and offer complex problem-solving situations where the learner has to find creative and practical solutions for the problems (Prensky, 2009). Research also suggests that game-based learning has a potential to impart deeper learning, which occurs when students routinely use higher-order cognitive skills, such as critical thinking, analysis, problem-solving, and decision-making while describing their own meta cognition and applying these skills in dealing with real-world experiences (Kolovou & Heuvel-Panhuizen, 2010; Liu, Cheng, & Huang, 2011; Spires, Row, Mott, & Lester, 2011; Ya-Ting, 2012).

3.3 Independent Variables of the Study—Academic Achievement

Defining student academic achievement is not easy, but it can be considered an education outcome and an indicator of the extent to which a student has achieved success in meeting his or her short-term or long-term goals in education. The most common indicator of achievement usually refers to student performance in an academic area measured by achievement tests. Others define academic achievement as earning a degree or a certain grade point average.

3.3.1 Importance of academic achievement

Academic achievement indicates the level at which an individual has accomplished specific goals in instructional environments. It helps give an indicator of the knowledge that has been acquired by the learner. Academic achievement helps in determining whether a student will be capable of continuing education, such as being admitted to tertiary school, and influences one's career. Apart from the advantages for the individual, it is also required for the wealth of a nation and its prosperity. There is a strong correlation between a nation's level of academic achievement and positive socioeconomic development (Schiller, Khmelkov, & Wang, 2002).

3.3.2 Measuring academic achievement

Researchers have studied different ways of measuring student achievements such as dropout rates, academic proficiency, or other factors indicating the effectiveness of the learning and teaching methods. Student achievement can also be measured by the accomplishment of learning objectives and the acquisition of competencies or skills.

The most common and easy method for measuring student academic achievement is standardized testing. The assumptions behind standardized testing are that they are designed with objectives in mind and are intended to make an accurate assessment of a student's academic knowledge. These assumptions have played a role in convincing schools worldwide to use test data to determine a student's academic ability.

Student assessments at the classroom, state, national, and international levels are used worldwide frequently to evaluate student achievement in any particular subject. The results of these assessments help gain an understanding of the levels of students' proficiency and a comparison of their performance with other students.

3.3.3 Impact of game-based learning on achievement

Many researchers have studied the educational purpose of games. However, because of the complex nature of assessments and measuring academic achievement, there was no definitive measure against which the impact of learner achievement of outcomes could be explored. Instead, a variety of outcomes were examined in such studies. For instance, some studies reported on the extent of knowledge gained by students (Chuang & Chen, 2009; Huizenga, Admiraal, Akkerman, & Dam, 2009; Papastergiou, 2009), while others explored the impact of 21st-century skills, such as problem solving or critical thinking (Kolovou & Heuvel-Panhuizen, 2010; Liu et al., 2011; Spires et al., 2011; Ya-Ting, 2012). Academic achievement was generally referred to as an outcome, however, without detailing the specific measure, making it difficult to understand the exact impact. Similarly, assessment methods vary widely; some studies used standardized tests to measure achievement against traditional practices, while some used tests developed for the purpose of the study. Overall, literature indicates some degree of improvement in problem-solving skills and knowledge acquisition (Chuang & Chen, 2009; Kebritchi, Hirumi, & Bai, 2010; Miller & Robertson, 2011), while others found no gains in academic achievement (Annetta, Minogue, Holmes, & Cheng, 2009; Fengfeng, 2008; Spires et al., 2011; Ya-Ting, 2012). One explanation for less positive results around academic achievement could be the methodological design of the study, such as a possible mismatch between traditionally measured outcomes and those facilitated by the games. Moreover, the limited period of the intervention where studies are not conducted over a substantial amount of time may also result in low academic achievement.

3.4 Independent Variables of the Study—Engagement

Although engagement is very important and has a positive effect on learning, its definition cannot be easily described. It can be deemed as student willingness to participate in normal school activities such as following the teacher's instructions or submitting work as required. It may share some qualities with student motivation, but the two are completely different.

Interest in student engagement has seen quite a lot of growth, even though how it is defined has varied little. Student engagement was primarily defined by behaviors that could be observed such as student participation (Brophy, 1983; Chapman, 2003). Later emotional or affective components were also added to the concept (Connell & Wellborn, 1991), including emotions and feelings of attachment, belonging, and enjoyment. The most recent idea is cognitive engagement, which depends on the student's investment in learning and strategies applied (Fredricks, Blumenfeld, & Paris, 2004).

Student engagement is very critical for learning. Educators these days have to keep students' interest at the highest level possible. Disengagement could lead not only to lower achievement but also to student misbehavior and negative attitude. As students get older, their engagement level falls to the extent where lack of interest in school work could result in low levels of motivation and dropouts.

Research shows that student engagement can predict any success or achievement in school. According to Finn and Rock (1997), engagement has two major components: an emotional component of identification and a behavioral component of participation. Later, other quite influential models distinguished between engagement and disaffected actions, and defined engaged students as those who show some involvement during discussions, whereas disengaged are those who gave up easily or showed negative emotions during classroom tasks (Connell & Wellborn, 1991; Skinner & Belmont, 1993).

The newer definitions of engagement focus on many different components instead of the earlier one-dimensional models. Theoretically, engagement includes students' behavior and their physiological or emotional attachment to the school. The most well-known and acknowledged framework of engagement as proposed by Fredricks et al. (2004) includes the cognitive, behavioral, and affective indicators. In addition to this three-component model, researchers recently proposed a fourth subtype of academic engagement that integrates all the theoretical works and aims to provide an understanding of the relationship of the learning environment and levels of engagement (Opdenakker & Minnaert, 2011). It provides the extent to which students do well in school.

Student engagement shows a positive correlation with achievement and a negative correlation with the dropout rate (Fredricks et al., 2004). Engaged students have a higher chance of getting better grades and of performing better in standardized tests (Marks, 2000; Fredricks et al., 2004). Student engagement declines as children grow older, and it reaches the lowest state around high school (Marks, 2000). The study led by Marks showed that around half of students were disengaged when they were in high school. Thus, student engagement is a primary goal for all school improvement efforts and should be measured to identify any bottlenecks and improvements.

Over time, older disengaged students might drop out of school and face many difficulties in finding jobs.

Engagement is a difficult phenomenon to measure. The most frequent way of measuring it is through questionnaires called student self-report measures, which students themselves fill out. Other ways include rating scales and checklists, known as teacher report measures, filled out by teachers when they observe students or converse with them. The last method involves external observations that may be done by school administrators, teacher peers, or trained observers.

3.4.1 Cognitive engagement

Cognitive engagement is when a student spends some mental effort to comprehend complex ideas and thus acquires the most difficult skills (Fredricks et al., 2004). Students demonstrate concentration and try achieving goals while coping with failures. Cognitive engagement can be seen as the psychological efforts of a child when he or she is learning. It can be differentiated from the high performance of a student who may show good performance, but may not exhibit motivation to put in more effort than what is required. Examples of this type of engagement include a preference for working hard and flexibility in problem solving.

There are very limited methods for measuring cognitive engagement. They mostly involve self-report surveys, which ask about independent work styles, hard work preference, and ways to cope with any failure (Connell & Wellborn, 1991). A lot of the questions also involve intrinsic motivation and ask how students set strategies for studying such as attention or relation of any new knowledge.

Observation may also be used to measure cognitive engagement. This involves noticing indicators such as students' monitoring of their work, justifying of their answers, or expending effort to complete tasks (Helme & Clarke, 2001).

3.4.2 Behavioral engagement

Behavioral engagement can be seen when a student participates in social, extracurricular, or academic activities. One important aspect of this type of engagement is the change in behavior leading to good performance, including communication and collaboration with peers. Behavioral engagement also helps in cognitive engagement as it makes sure students are demonstrating interest via their behavior. This can be manifested in various examples of positive conduct such as asking questions, studying, participating in activities and discussions, completing homework, etc. (Connell & Wellborn, 1991; Finn, 1989). This type of engagement can be easily measured since assessing student behavior is easy. Most assessments usually compare negative behaviors with positive ones.

Behavioral engagement is most frequently measured through self-report surveys, teacher ratings, or observations (Finn & Rock, 1997) involving different indicators of positive behavior such as following rules or completing class work/homework. Indicators of negative behavior may include frequency of absenteeism, interfering with other students' work, or talking to peers. Scales set on work-related aspects include attention, persistence, and effort. Other scales cover students' participation in extracurricular activities (Finn & Rock, 1997).

Behavioral engagement is also measured through observations (Stipek, 2002). Scales, ranging from off-task to deeply involved, are used to describe student behavior such as attentiveness, finishing any work assigned, or being enthusiastic. The final way of measuring behavioral engagement is through focus group discussions and case studies, which help in collecting detailed accounts of students and their interaction with peers.

3.4.3 Affective engagement

Affective engagement is a representation of feelings and attitudes involved in learning (Skinner & Belmont, 1993). Positive attitudes towards academic activities show positive affective engagement and are demonstrated through students' personal attitudes and appreciation and feelings about their work. Thus, affective engagement is when students develop an emotional bond with their peers, teachers, and school.

The most common way to measure affective engagement is through self-report surveys that ask questions about teacher-student relationship or any emotions and values related to school or academic work (Stipek, 2002). The questions mostly ask students to rate their interest in learning tasks and to record their feelings of excitement when trying new projects (Chapman, 2003).

3.4.4 Review of literature on the impact of game-based learning on engagement

Fengfeng (2008) conducted research using a mixed-method approach to examine the effects of educational computer games on math achievement, metacognitive awareness, and positive attitudes toward math learning. The study was carried out on a group of 15 students in fourth and fifth grades by employing a series of web-based games, ASTRA EAGLE, during their summer math program. The instruments used for collecting results included attitude surveys, questionnaires, an infield observation protocol, and a game skills arithmetic test of 30 items. The results showed that (1) students demonstrated more positive attitudes towards math learning because of the gaming sessions, but they did not show any difference in test performance; and (2) not all math games are equally engaging for children; engagement depends on the activities in the game story (Fengfeng, 2008).

Schaaf (2012) compared DGBL activities with effective, research-based, learning strategies for collecting observations about any variances in time on task behavior and student engagement. The students were randomly selected from Grades 3 through 5, and their data were collected using attitudinal surveys and student time on task observations during eight lesson cycles. The instructional strategy for half of the students was DGBL using the Candy Factory and Pearl Diver games, while a different strategy was devised for the others. The trials resulted in a greater number of DGBL groups showing higher student engagement and time on task behavior than the groups that used alternative strategies (Schaaf, 2012). However, the opposite was also sometimes observed. Schaaf (2012) concluded that DGBL can produce similar levels of engagement as other research-proven learning strategies, but it cannot always be considered the best practice for teaching and may be incorporated only when fun and engaging experiences for students are needed.

Annetta et al. (2009) carried out a quasi-experimental study for evaluating a video game created by a teacher on genetics (MEGA) in terms of its cognitive and affective impact on the students who used it. The experimental group consisted of 66 students, and the control group consisted of 63 students from four classes in a high school. A genetics unit test score and assessments using The Protocol for Classroom Observations were used to arrive at the result. Annetta et al. (2009) saw no difference in student learning by employing a 90-minute session of game play on desktop computers, but found a substantial difference in the engagement levels of the participants while they interfaced with the video game.

Huizenga et al. (2009) investigated the effects of a mobile city game on engagement, motivation, and learning. The game used was Frequency 1550, which was based on historical knowledge of Amsterdam and developed by the Waag Society. The authors used a quasi-experimental approach on a sample of 485 students from 20 classes in five schools. Half of the students played the mobile history game, whereas the other half received regular, project-based, class lessons. Students' engagement levels were observed and recorded on observation sheets, and the motivation levels were measured by adapting a questionnaire used in earlier studies. Students' knowledge of the topic was gauged by collecting scores from a designed subject test consisting of 30 questions. Huizenga et al. (2009) concluded that the experimental group who played the game demonstrated higher levels of engagement and more knowledge gain compared with the control group, but they saw no noticeable difference in the motivation levels regarding the subject between control and experiment groups.

Facer et al. (2004) developed a mobile game named Savannah to encourage the development of children's conceptual understanding of animal behavior. They conducted a study to explore children's use of the game and investigate what they learned after playing it. The game was tested on a group of 10 children aged 11 to 12 years old through two activities where they acted as lions using personal digital assistants with GPS capabilities as mobile clients to a personal computer-based game server. Interviews and observations of the students were captured for the analysis. Students demonstrated high levels of engagement and enjoyment by playing the game; thus, the prototype offered an interesting insight into the extent to which mobile gaming can be used to support learning and highlighted some challenges with this learning format and resource design (Facer et al., 2004).

Samur (2012) devised ways for measuring engagement to investigate the effects of educational games and virtual manipulatives. The study was based on a quasi-experimental design consisting of three experimental groups and one control group, each consisting of students from a fifth-grade classroom. The participants of the experimental groups played Candy Factory and Pearl Driver, and performed activities with virtual manipulatives. At the same time, the control group's participants did paper and pencil drills. Based on engagement surveys, the engagement levels were higher in the participants of the educational games groups than in the other groups (Samur, 2012).

3.5 Independent Variables of the Study—Motivation

Although most instructional designers agree on the importance of the motivation variable, defining it is quite difficult as it is a hypothetical construct, and it cannot easily be measured scientifically. Educational psychologists describe the term motivation as the mental processes that help in energizing and giving direction or purpose to transform behavior (Kleinginna & Kleinginna, 1981a). Motivation can change depending on many influences and involves a variety of interests, values, perceptions, and closely related actions. Different definitions of motivation abound. However, most of them belong to two major categories: physiological and psychological. The physiological definitions of motivation deal with bodily functions that can be measured and generally use the term "energized" for describing it. The psychological definitions of motivation consider its cognitive aspects. Motivation can be broadly defined as the attribute that makes people do or not do something: intrinsic motivation involves pleasure or interest, whereas extrinsic motivation is usually driven by external desires for some reward (Broussard & Garrison, 2004).

3.5.1 Importance of motivation

The positive correlation between learning and motivation has almost universal acceptance. Dewey (1938) explained that the most important attitude is the desire to learn: if a person has more motivation about any particular subject, he or she will get more chances to learn about it. Malone (1981) noted that intrinsic motivation helps in spending more time and effort in learning, and helps in feeling better about learning. Schunk and Zimmerman (2007) consider motivation the most important factor while building a virtual university. Understanding motivation is very important so it can be used effectively during the instructional design process. Knowing the conditions that help energize human behavior is necessary for understanding motivation. Lastly, great attention should be paid to instructional designers when instructional games are created.

3.5.2 Measuring motivation

Motivation is commonly assessed through self-report measures or rating scales completed by parents or teachers. These instruments are based on different subscales such as attributions, self-efficacy, interest, self-perception, curiosity, persistence, and enjoyment of learning. Some examples of well-known instruments are the Children's Academic Intrinsic Motivation Inventory (A. E. Gottfried, Fleming, & Gottfried, 2001), Scale of Intrinsic Versus Extrinsic Motivational Orientation in the Classroom (Harter, 1981), and Instrumental Competence Scale for Children (Lange & Adler, 1997). However, when any of these instruments are used with primary schoolchildren, modifications need to be made to reduce any load caused by the language, such as reading the items out loud and simplifying the rating scales.

Behavioral indicators can also measure motivation. Some studies use free choice persistence that measures time spent on an activity once rewards are no longer present (Deci, Koestner, & Ryan, 1999). Another aspect that can be measured is effective strategy use that includes behaviors such as organization, rehearsal, or comprehension during reading. Persistence can also be noted if one is talking to himself/herself when doing a task or asking for any help. Learners with high motivation levels keep their persistence high even while doing challenging tasks, whereas learners with low motivation levels are seen decreasing efforts in such cases.

3.5.3 Review of literature on the impact of game-based learning on motivation

Ouahbi, Kaddari, Darhmaoui, & Elachqar (2014) used games to teach a basic programming course and evaluated the teaching approach. Their study had a group of 40 Moroccan secondary school students participating; half of the students used the Scratch game environment to create animated English stories, while the other half followed traditional Pascal programming classroom methods. Motivational surveys at the start and end of the research concluded that students using the Scratch game environment were more motivated and became autonomous learners compared with the students who followed traditional Pascal programming methods.

Treviño-Guzmán and Pomales-García (2014) tested a computer game focusing on fundamental industrial concepts on 44 freshman and pre-college students. They collected data through interviews and pretest and post-test questionnaires disseminated via an online local questionnaire system. The results indicated that students were more motivated to pursue higher education after the gaming activity and had developed more understanding about the content knowledge (Treviño-Guzmán & Pomales-García, 2014). The authors concluded that games could be a good tool for recruiting and motivating the best talent available.

Su and Cheng (2013) developed a 3D game for teaching software engineering concepts to assess students' levels of motivation, satisfaction, and learning achievement after playing the game. They used a quasi-experimental design and had 63 tertiary-level students as study participants. The game was designed to teach the waterfall development model, a unit of software engineering curriculum. The experimental group used the game-based learning technique, whereas the control group used the traditional face-to-face learning. Pretests and post-tests were conducted to measure students' achievement, and motivational surveys were administered to investigate the effectiveness of the teaching method. The results revealed higher levels of learning achievement and motivation in the experimental group students who used the 3D game-based approach than the control group students, and indicated that game-based learning was more popular among the students because the challenges ignited curiosity and immersion in the learning activities (Su & Cheng, 2013).

Ya-Ting (2012) investigated the effectiveness of DGBL on students' problem-solving skills, learning motivation, and academic achievement. The study was based on a quasi-experimental design where 44 secondary school students were tested in the subject Civics and Society. Half of the students were taught via traditional instruction, and the other half through DGBL. Pre- and post-tests for measuring problem solving and learning motivation were held during a semester-long period. The experimental group students showed higher motivation and improved problem-solving skills as compared with the control group, but no considerable difference was found in the achievement data between the groups (Ya-Ting, 2012).

Charsky and Ressler (2011) used an off-the-shelf computer game called Civilization III to examine student motivation in learning History concepts. Grade 9 students aged 14 to 15 were divided into one control and two experimental groups. The control group was taught through routine classroom teaching, the first experimental group learned history by playing the game, and the second experimental group drew concept maps alongside playing the game. The motivation levels were measured through motivational surveys before and after the intervention; results revealed the highest motivation level among the students who played the game (Charsky & Ressler, 2011).

Kebritchi et al. (2010) examined the effects of a mathematics game on students' achievement and motivation along with the influences of any prior knowledge, English language, or computer skill. The participants of their study included 193 students and 10 teachers from a secondary school. The students were introduced to a set of educational games called DimensionM for a period of 18 weeks. The data were collected using motivation surveys and academic achievement tests. The authors saw no difference in the motivation levels of the control and experimental groups, but they observed significant improvement in the achievement of the experimental group.

Papastergiou (2009) made a comparison of an application, LearnMem1, which contained game-based elements, with another application, LearnMem2, which lacked game elements. Both the applications were based on a Greek secondary-school computer science curriculum outlining the same learning objectives. A computer memory knowledge test along with observations was administered at the start and end of the intervention. The results indicated a positive increase in engagement, effectiveness, and activeness in learners who used the game-based application compared with those who did not. However, Papastergiou (2009) also noticed that while games helped improve motivation, there was a potential risk of distraction from learning. Regarding gender differences, the study found no notable impact on learning gains despite the fact that boys were greatly involved in the computer games in comparison to girls.

Whitton (2007) questioned the assumption that games are a useful education tool because they motivate students. The author recorded students' motivation levels and perceptions using 12 in-depth interviews followed by a large-scale survey of 200 students. The results showed that majority of the students who participated in the study did not find games motivating at all, and thus there seemed to be no link between students' motivation to play games for recreation and using them for learning purposes. However, the study highlighted that students may be more motivated to play games for learning if these are based on sound pedagogical principles.

3.6 Impact of Game-Based Learning on Efficiency, Equity, and Accessibility

In terms of efficiency, game-based learning offers a number of advantages such as being cost-effective, having a very low physical risk for the learner, having a tailored pace according to the needs of the student, offering standardized assessments, and being engaging to the learner (Trybus, 2009). This type of learning helps promote the skills required for responding under pressure and helps learners think about real-world challenges while giving them interactive experiences. Another advantage of game-based learning is the improvement of skills such as critical thinking, decision-making, knowledge construction, and discovery learning. The user-centered aspects of a game help increase visual and verbal skills by increasing the response time and attention span of the learner (Gros, 2007). As games promote learning by doing, they allow learners to develop leadership skills and learn from their mistakes. Immediate rewards and instant feedback help boost confidence and encourage rational thinking. Finally, game-based learning aids in improving accuracy, memory, retention of information, and testing hypothesis (Hong et al., 2009).

3.7 Literature on Game-Based Learning in Mathematics Education

Future learning is always built upon the foundation of the earliest education received by a child (Ray & Smith, 2010). Recent years have seen the need for improving children's reading skills, but in a world connected by information and communications technology (ICT), mathematics proficiency has become as important as literacy (National Center for Education Evaluation and Regional Assistance, 2013). Children who were unable to develop the requisite informal mathematics knowledge in their early years face problems with formal mathematics when they start school and later start to fall behind their peers. Children who showed low achievement in mathematics at low grade levels later show even slower growth as they mature (Bodovski & Farkas, 2007). Their early knowledge is very much a predictor of their later success in the subject, and constant problems in this subject are usually the only reason for failing high school and not entering tertiary school (Appleton & Lawrenz, 2011).

Recent research shows that age-appropriate and well-designed digital games can provide an individualized, student-centered, learning experience that is effective for developing math skills and fostering inclusive learning. Outhwaite, Gulliford, and Pitchford (2017) found an inverse relationship between the repetitive and interactive features of digital games and cognitive tasks demand: the more repetitive and interactive the game, the less the cognitive task load on students, which is particularly beneficial for underachieving students with poor memory skills. Apparently, interactive tablet-based interventions that incorporate these features are likely to reduce the gap in math attainment over a period of time.

Educational games may also affect student attitudes towards subjects in a positive manner, especially in higher primary and lower secondary students (Coştu, Aydin, & Filiz, 2009). In the study led by Coştu et al, 2009, the students reported the advantages of learning through games and showed positive attitudes towards the use of game-based learning in mathematics classes.

In one study, Ke (2008) looked into the potential of implementing computer mathematics games as an anchor for tutoring math. Findings suggested that game-based tutoring is dynamic in terms of its timing, initiation, content, style, and tutee reaction created, and students' state test performance improved (Ke, 2008). The study can serve as a catalyst for further research into using educational gaming as an instructional artifact to augment other instructional approaches.

Chang, Evans, Kim, Norton, and Samur (2015) examined the effects of a learning game, [The Math App] on the mathematics proficiency of middle-school students. For the game intervention condition, students learned fractions concepts by playing [The Math App]. In the analysis, students' mathematical proficiency levels prior to the intervention were taken into account. Results indicate that students in the game intervention group showed higher mathematics proficiency than those in the paper-and-pencil group.

Another study carried out by Warren, Thomas, and Devries (2014) indicated that as culturally appropriate mathematical learning activities were introduced into a learning environment, the teachers became more aware of children's understanding of mathematics and how they could engage in teaching mathematics while maintaining their philosophy of play. Thus, they were able to adapt their pedagogies to suit the diverse needs of their students.

Considering the importance of mathematics to academic success in all subjects, all children must develop sound knowledge of this subject in their early years. For this reason, an early and effective intervention is needed to close any gaps present in their formal knowledge (Clements & Sarama, 2009). Facilitation of mathematical learning at the start can have a strong positive effect on students' lives later and helps build foundational competencies required for their future. It is time to switch the mindset of teachers and parents to one that places equal emphasis on reading and mathematical reasoning, starting with preschool to create a smooth path for children's learning in their early grades.

Most of the past research has focused on a curriculum that is based on a level higher than middle school because it is easier to collect results via student-answered surveys and questionnaires. Primary-school research is more difficult to carry out because of a number of limitations, and thus it has been avoided greatly. Also, very rarely have researchers used their own application, designed with the same objectives of classroom instruction in mind, to carry out the research. There is little evidence of developed applications tested on handheld mobile technologies such as tablets in the classroom, as instead they were carried out on desktop or laptop computers. Since the personal computer boom is gradually decreasing with the increased use of smartphones and tablets, it is very important to see the effect of these newer emerging technologies in education.

IV. METHODOLOGY

4.1 Project Setting

This study was conducted on students from an extremely low socioeconomic background. These children were enrolled in out-of-school children school, an initiative of the non-government organization International Foundation for Education, Empowerment, and Learning located inside public school buildings. Nineteen branches of OSCSs are operating in Islamabad. A vast majority of its students belong to extremely poor households and support their parents in earning a living. The aim of these schools is to provide free quality education to poor children who have never gone to formal school because they are overaged or financially constrained, and students who dropped out of school after being enrolled.

4.2 The Game Selected for the Intervention

The educational game used in the study was selected from the pool of learning applications already developed by a team of students from the National University of Sciences and Technology (NUST) Master's Program of Innovative Technologies in Education. The selected game, Measure Land, targets Grade 1 to Grade 5 pupils and uses a self-paced fast track or "speed literacy" learning, in and out of schools, using low-cost tablet technology. This game covers learning outcomes under the topic Measurements in the National Curriculum. Through guided narration and bilingual game instructions, students were taught measurement concepts and involved in a series of interactive activities based on Bloom's Taxonomy to master the content. Positive reinforcement was provided throughout in the form of constructive feedback and rewards. At the end of each level, students were shown the progress they achieved, which encouraged them to learn mathematics with more enthusiasm.

The prominent features of the game selected are:

- Supports Android 4.0 and above
- Self-paced fast-track learning from Grade 1 to Grade 5 on the topic of measurements
- Learning outcomes aligned with the National Curriculum of Mathematics
- Step-by-step bilingual instructions (English and Urdu) to enhance students' understanding of the concepts
- Interactive activities for students' cognitive development
- Caters to the needs of auditory, visual, and kinesthetic learners
- Embedded assessments, rewards, and feedback
- Easy game mechanics
- Vibrant graphics based on everyday themes and scenarios to support meaningful learning.

Following are the objectives of the game and the issues under consideration.

- Game activities were to be designed with interfaces such as child-friendly and animated characters, which would suit young children.

- Game activities were to aid the learning of concepts and prevent a child from paying attention only to fun and bright visuals. Thus, balance was required.

- The difficulty level of the game activities was to match students' age and skills set. Activities would start with an easy level and become more challenging as the game progressed. Activities were not to be very easy that children could play everything without trying to think about it. However, these must also not be highly challenging to the point that playing frustrates them.

- Each game activity would have a set of goals the children could identify so they could take ownership of their own learning. The difficulty level of the goals would become more challenging to further improve the children's understanding of the concepts. The progression through difficulty levels in achieving goals would enable self-paced learning.

- Feedback and rewards would supplement each game activity. Feedback would help the pupils evaluate their choices, and rewards would help them get a feeling of achievement.

- Game scenarios were to be based on real-life situations to enable students to apply the concepts in their daily lives.

4.3 Research Design

The study employed a mixed-method, quasi-experimental research design with control and experimental groups. The significance of achievement, engagement, and motivation because of DGBL was determined using quantitative data, while insights to issues related to DGBL were established through qualitative data.

There was an equivalent representation of students in each group: 100 students in the experimental group and 100 students in the control group. For this design, both groups took a pretest before the treatment and a post-test at the end of the treatment.

The experimental group was taught the topic Measurements from their math syllabus through game-based teaching via tablet technology, whereas the control group was taught the same topic through traditional teaching pedagogies.

4.4 Research Sample

4.4.1 Students

A sample size of 200 students enrolled in Grade 1 and aged 8 to 15 years old was selected from seven out of 19 different branches of OSCSs in Islamabad. A purposive sampling approach was adopted for selecting schools, dependent mainly on the availability of Grade 1 pupils. Few branches had no Grade 1 pupils available.

4.4.2 Teachers and Head Teachers

A total of 11 class teachers and four head teachers from the selected schools were also included in qualitative data collection. The teachers and head teachers involved in the study differed a little in their instruction styles, personalities, and years of experience, which could not be controlled in the study.

Table 1 below presents the summary of the distribution of data in selected schools.

Table 1. Distribution of Data Across Schools

Sr. No.	School Name	Students in Control Group	Students in Experimental Group	No. of Teachers	No. of Head Teachers
1.	OSCS I-8 Branch	23	21	2	1
2.	OSCS F-11 Branch	26	29	2	1
3.	OSCS H-9 Branch	11	9	2	1
4.	OSCS I-9 Branch	9	10	1	–
5.	OSCS G-14 Branch	10	11	1	–
6.	OSCS F-12 Branch	9	10	1	–
7.	OSCS Tarnol Branch	12	10	2	1
Total		100	100	11	4

4.4.3 Demographics

The students involved in this study varied in age range and belonged to the extremely low-income group. A typical Grade 1 cohort was composed of students ranging in age from 8 years to 15 years. Most of the children also had part-time jobs, such as selling fruit or vegetables at the local market, or working at the local car wash, to help their parents earn a living. Figure 1 represents the socioeconomic background of the students selected for this study.

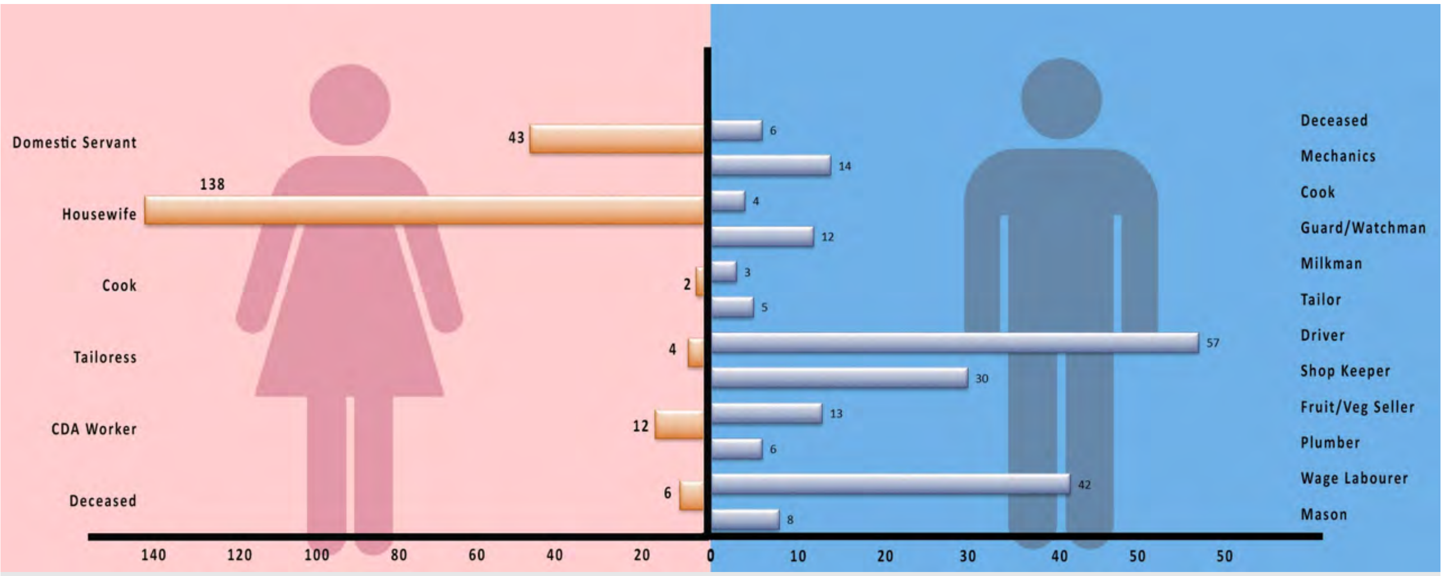

Figure 1. Demographics of Study Participants

4.5 Data Collection

Data were collected through quantitative and qualitative tools. Table 2 presents a summary and data collection tools.

Table 2. Summary of Data Collection Instruments

Variables	Data Collection Tools
Learning Beliefs	Baseline survey to assess learning beliefs about mathematics learning
Engagement	Direct observations, video recordings of examining engagement and classroom activities, Behavioral Observation of Students in School (BOSS)
Motivation	Instructional Material Motivational Survey (IMMS)
Achievement	Pre- and post-tests based on math curriculum of the selected topic
Teachers' and Head Teachers' Perceptions	In-depth interviews with teachers and head teachers to gain insights into the use of game-based learning to provide quality education to out-of-school children
Student Perception	Focus group discussions with students to gain insights into the issues related to tablet-based learning in class and how it will affect their future education

4.5.1 Learning Beliefs

Prior to the deployment of the study, a baseline survey was conducted among 400 participants of the same age group (8-15 years) belonging to the low-income group and enrolled in all the 19 branches of OSCSs in Islamabad. The purpose was to gather data on the approaches to learning mathematics, which informed the data analysis after the intervention.

4.5.2 Video Recordings/Direct Observations to Measure Engagement

Student engagement was observed using video recordings. Videos were recorded of each classroom lesson of the control and experimental groups, and focused on four to six students at a time. These video recordings were watched later to gather data on student behavior.

The instrument called Behavioral Observation of Students in Schools (BOSS) (Shapiro, 2011) was used to collect data on student engagement. School psychologists developed BOSS, which has a high (90–100%) inter-observer reliability, to screen children, especially those at risk of academic failure, and to enable school psychologists, researchers, and evaluators to track the effectiveness of interventions over time (Volpe, Diperna, Hintze, & Shapiro, 2005).

Prior to the study, a team of observers was trained on the use of the BOSS tool to observe student engagement in schools. A pilot test was also conducted to test the efficient use of the tool as well as observers' ability to use the tool effectively during the course of the research.

The BOSS Code was used to systematically record behaviors in a school environment. Each 15-second interval was coded along five categories of engaged time (two categories of engagement and three categories of non-engagement). Engagement categories include active engagement, coded when the observed student is actively engaged in assigned work (reading aloud), and passive engagement, coded when the observed student is passively attending to assigned work (listening to a lecture). Non-engagement is coded for an observed interval when any of the following is observed—off-task motor (engaging in any out-of-seat behavior), off-task verbal (making unauthorized comments and remarks), or off-task passive (staring out the window).

4.5.3 Data Coding Using the BOSS Instrument

The BOSS application contained buttons labeled with specific behaviors to be tapped while a student was being observed. The different codes available for engaged times are active engaged time (AET) and passive engaged time (PET), while the codes available for off-task times are off-task motor (OFT-M), off-task verbal (OFT-V), and off-task passive (OFT-P). At the beginning of each cued interval, the observer looked at the targeted students, determining whether the student is on task and, if so, whether the on-task behavior constitutes an active or passive form of engagement.

Active engaged time (AET) was considered when students were actively attending to the work assigned to them, while passive engaged time (PET) was coded when students were passively listening or attending to the work assigned. If a student was not engaged, the behavior was coded as off-task motor to indicate instances of motor activities, off-task verbal to indicate any extra audible verbalizations, and off-task passive to indicate if students were not attending to their assigned activity for a minimum period of three seconds. The occurrence of behavior at a particular moment was recorded by tapping the appropriate button on the observation screen of the BOSS application.

Some examples of the codes are given in Table 3.

Table 3. Data Coding Examples of BOSS Instrument

Variables	Indicative Activities
Active Engaged Time	Writing Reading aloud Raising a hand Talking to the teacher Tapping on an answer Dragging objects
Passive Engaged Time	Reading material silently Listening to the teacher's lecture Listening to the game instruction Looking at the board when teacher teaches Looking carefully at animation Listening to peer answering question
Off-Task Motor	Playing with random object such as eraser, pencil Touching others items or tablets Out of seat Randomly tapping on screen Turning around in seat Flipping pages of book randomly
Off-Task Verbal	Making random sounds Talking to friends / peers Making any unauthorized remarks Giving answers when teacher has prohibited
Off-Task Passive	Looking randomly around the room Listening carefully to other students talking about things other than classwork Staring at the wall, window, etc.

4.5.4 Surveys to Measure Motivation

The impact on motivation of the instructional materials—digital games for the experimental group and traditional paper-based worksheets for the control group—was measured using the Instructional Material Motivational Survey (IMMS), based on the attention, relevance, confidence, and satisfaction (ARCS) motivational model (Keller, 1987).

The survey questions were adapted from Keller's ARCS model that was designed to assess how the instructional material could affect learner motivation (Rodgers & Withrow-Thorton, 2005). A total of 36 questions helped gauge motivational reactions towards self-directed instructional material on a five-point Likert scale in the subcategories of attention, relevance, confidence, and satisfaction. This instrument is reported to have high validity, with a reliability coefficient of 0.96, and is widely used in research studies that are inclined to evaluate the learner performance of DGBL following motivation stimulation (Woo, 2014; Kebritchi et al., 2010; Liu & Chu, 2010; Liu, 2014).

4.5.5 Achievement—Pretests and Post-tests

The knowledge tests were planned to provide a measure of the students' understanding of the concepts. A pretest was administered to both groups (control and experiment) prior to the intervention. After two weeks of intervention in each selected school, a post-test was conducted to measure the learning gains, if any. Each test was designed to measure responses against the target learning outcomes from Grade 1 to Grade 4 on the topic of measurements.

4.6 Improvements in Methodology

This section highlights the necessary changes initiated to improve the proposed methodology. These changes were implemented in certain contexts to further improve the data collection process.

4.6.1 Adaptation of BOSS Tool

As discussed earlier, the BOSS tool was used to measure engagement. Due to funding constraints, the tool could not be purchased for each observer. Therefore, the developers volunteered to create a similar tool on the Windows platform which can be installed on a laptop for efficient observation process. The adapted tool was thoroughly tested to maintain consistent, high, inter-rater reliability. The observers underwent extensive training on mock videos to conduct observations using to this tool.

4.6.2 Localization of Survey Questionnaires

Since the target population was not well-versed in English, following World Health Organization guidelines, the survey questionnaires were translated from English to Urdu.

The following steps were followed for the translation process.

- Forward translation from English to Urdu language
- Expert panel back-translation from Urdu to English
- Comparison of original and back-translation
- Iterations to fully match the original and back translation
- Pretesting and cognitive interviewing with 30 students
- Creation of a final version in Urdu.

4.6.3 Survey Management of Children

It could be tricky obtaining maximum survey responses from children who may not be able to fully comprehend the information or may lose interest in filling out survey forms. Therefore, extra care was taken to elicit authentic responses, making the survey process as pleasant as possible. The following measures were adopted:

- *Introduction of participatory approaches (Save the Children, 1997).* Each subscale in the Likert scale was represented by a corresponding symbol—a "smiley." Students were asked to color in the symbol that best described their feeling with regard to the question. To prevent getting responses corresponding to their favorite smiley, the authors divided the students into small groups along with data enumerators and had them monitored for thoughtful responses rather than random patterns.

- *Shuffling of survey questions to get maximum responses.* Another major perceived issue was boredom or losing interest towards the end of the survey, which may result in random responses to questions at the end of the survey. Hence, six sets of questionnaires were created by shuffling the questions in the survey forms. This strategy ensured thoughtful responses to all questions from the target cohort.

- *Warm-up and cool-down activities.*
  To improve student attention while filling out the survey forms, a one-minute fun activity (e.g., playing catch-the-ball) was introduced every 10 minutes. This activity helped re-boost student energy so they could concentrate on the survey questions.

4.7 Data Analysis

To compare results of the experimental and control groups, appropriate statistical parametric and non-parametric tests were applied using SPSS quantitative data analysis tool.

4.7.1 Data Analysis of Engagement Scores

Total engagement time will be the sum of AET and PET. BOSS Total Engaged Time Scores were analyzed using SPSS software to find any statistical differences in engagement levels of the control group and the experimental group.

Descriptive analysis was applied to the Total Engaged Time Score to find mean, standard deviation, and standard error mean. Considering the nature of the data, parametric or non-parametric tests were applied for further analysis and to identify the significant difference between the two groups.

4.7.2 Data Analysis of Motivation Survey Scores

Similarly, data obtained through IMMS were analyzed using SPSS. Descriptive statistics were run to get the mean score values. To check whether differences are significant between the control and experimental groups, further analysis was performed on the Total Motivation Scores, which is the sum of all the individual subscales of IMMS.

4.7.3 Data Analysis of Qualitative Data

The qualitative data gathered through interviews and focus group discussions (FGDs) were categorized into emerging themes for further analysis. NVivo was used to analyze qualitative data.

4.8 Informed Consent

Since the study involved observation through video recording, consent was sought from the study participants. The monitoring and evaluation (M&E) assistants, who were also responsible for data collection, were assigned to get informed consent from the study participants. These M&E assistants were graduates of social sciences, were well-versed in the local language, and had previous experience in research. They also received a thorough briefing on the process of taking consent prior to the study.

Written consent was obtained from the teachers and the head teachers to initiate the study in their schools. Verbal consent was sought from the students to participate in the study and be observed through video recordings. They were assured of the confidentiality of data.

V. FINDINGS

This section explains the research findings for the indicated research questions:

- Does game-based learning using tablets result in increased engagement, motivation, and academic achievement for primary school students of low socioeconomic background in learning mathematics?
- To what extent is it possible to practice self-paced learning in mathematics through a tablet-based app without the need of an instructor for the student?
- Do teachers find game-based learning using tablets an acceptable treatment for use in the classroom compared with traditional techniques for learning mathematics?

5.1 Measuring Student Academic Achievement

Students' knowledge on the selected topic of measurement from the National Math Curriculum was tested, before and after the intervention. A pretest was given before teaching the topic and a post-test was administered after the topic was covered completely. Each test contained 15 questions. The control group and the experimental group were given identical pre- and post-tests.

This section reports the comparison of achievement between groups (control and experimental), followed by the effect size calculated as Cohen's *d*.

5.1.1 Testing for Normality and Homogeneity

Before the appropriate statistical tests to compare the group means are chosen, an essential underlying assumption is to assess the normality of data and homogeneity of variance.

The normality of data was determined by employing the Kolmogorov-Smirnov test and the Shapiro-Wilk test at 95% confidence level ($\alpha = 0.05$) (see Table 4). Both tests indicated significant results ($p < 0.05$), suggesting that pretest and post-test data of the control and experimental groups were not normally distributed. However, no significant outliers were identified. Accordingly, the non-parametric test may be conducted.

Homogeneity of variance was determined using Levene's test. As Table 5 shows, results for pretest scores were not statistically significant ($F = 2.95$, $p > 0.05$), thus the assumption of homogeneity of variance was violated. However, Levene's test established homogeneity ($F = 17.345$, $p < 0.05$) for post-test scores, indicating that the assumption of equal variances was not violated.

Since not all data sets were normally distributed, and homogeneity was violated in one of the groups, a non-parametric Mann-Whitney U test was conducted to compare mean ranks of the groups instead of medians.

Table 4. Tests of Normality (Pre- and Post-Tests for Control and Experimental Groups)

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pretest Percentage Score	Control	0.140	100	0.000	0.907	100	0.000
	Experiment	0.164	100	0.000	0.909	100	0.000
Post-test Percentage Score	Control	0.119	100	0.001	0.963	100	0.007
	Experiment	0.172	100	0.000	0.942	100	0.000

Table 5. Homogeneity of Variance for Pre- and Post-Test Data

		Levene's Test for Equality of Variance	
		F	Sig.
Pretest Scores	Equal variances assumed	2.925	0.089
	Equal variances not assumed		
Post-test Scores	Equal variances assumed	17.345	0.000
	Equal variances not assumed		

[a] Lilliefors Significance Correction

5.1.2 Comparison of Pretest Scores Between Groups

Table 6 presents the descriptive statistics for the pretest scores of the two groups. Since the assumptions of normality and equal variances did not hold, a Mann-Whitney U test was carried out on the pretest scores (Table 7).

The control group was found to have a mean rank of 106.41 (N = 100), while the experimental group was found to have a mean rank of 94.59 (N = 100). The Mann-Whitney U value = 4409 with p = .148 ($p > 0.05$) indicates that no statistical significance was found between pretest scores of the control and experimental groups (Table 8). Hence, both groups were considered homogeneous in terms of their knowledge before the intervention started. Any difference in the scores found after the intervention was attributed to the treatment provided to the experimental group.

Table 6. Descriptive Statistics for Pretest Scores

Group	Mean	N	Std. Deviation	Minimum	Maximum	Range
Control Group	78.41	100	15.606	41	100	59
Experiment Group	76.63	100	12.718	50	100	50

Table 7. Mean Ranks for Mann-Whitney U Test (Pretest Scores)

	Group	N	Mean Rank	Sum of Ranks
Pretest Scores	Control	100	106.41	10641.00
	Experiment	100	94.59	9459.00
	Total	200		

Table 8. Significance and Statistics for Mann-Whitney U test (Pretest Scores)

	Pretest Scores
Mann-Whitney U	4409.000
Wilcoxon W	9459.000
Z	-1.448
Asymp. Sig. (2-tailed)	0.148
a. Grouping Variable: Group	

5.1.3 Comparison of Post-test Scores Between Groups

The post-test scores of the experimental and the control groups were also compared. The descriptive statistics for the post-test scores are given below in Table 9.

Table 9. Descriptive Statistics for Post-test Scores

Group	Mean	N	Std. Deviation	Minimum	Maximum	Range
Control Group	85.35	100	8.306	68	100	32
Experiment Group	91.84	100	5.325	80	100	20

Mean post-test scores were found to be higher in the experimental group (M = 91.84, SD = 5.325) than in the control group (M = 85.35, SD = 8.306). The control group had post-test scores ranging from 68 to 100, whereas scores in the experimental group varied from 80 to 100.

As noted in Table 4, data were not normally distributed. However, the assumption of equality of variance was achieved, therefore, the Mann-Whitney U test was carried out on the post-test scores (Table 10).

The control group was found to have a mean rank of 77.19 (N = 100), and the experimental group a mean rank of 123.81 (N = 100) (see Table 11). This was found to have statistical significance, *U* = 2669, $p < 0.05$, which implied that a statistically significant difference was found between the mean post-test scores of the experimental and control groups.

Table 10. Mean Ranks for Mann-Whitney U Test (Post-test Scores)

	Group	N	Mean Rank	Sum of Ranks
Post-test Scores	Control	100	77.19	7719.00
	Experiment	100	123.81	12381.00
	Total	200		

Table 11. Significance and Statistics for Mann-Whitney U test (Post-test Scores)

	Pretest Scores
Mann-Whitney U	2,669.000
Wilcoxon W	7,719.000
Z	-5.728
Asymp. Sig. (2-tailed)	0.000
a. Grouping Variable: Group	

5.1.4 Effect Size

The significance of the test does not automatically establish the strength of the effect of measures. Therefore, it is imperative to determine the effect size. For this study, effect size is measured using Cohen's d, defined as the difference between two means divided by a standard deviation for the data, i.e., the effect size is calculated using Cohen's d by dividing the difference between the means of the experimental and control group post-test scores by the standard deviation of the experimental group.

$$d = \frac{\bar{x}_1 - \bar{x}_2}{s}$$

Where, Cohen defined "s" as the pooled standard deviation (Cohen, 1988):

$$s = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$$

where the variance for one of the groups is defined as

$$s_1^2 = \frac{1}{n_1 - 1} \sum_{i=1}^{n_1} (x_{1,i} - \bar{x}_1)^2$$

and similar for the other group. Hence, using the above calculations, this study estimates a large effect size: $d = 0.9$.

The overall results indicate that a greater level of improvement in achieving the desired learning outcomes of the experimental group is attributed to the use of DGBL as opposed to traditional classroom instruction within the control group.

5.1.5 Self-paced learning

One aim of this research was to investigate the effectiveness of DGBL in achieving self-paced learning without the need of an instructor. For this purpose, the game Measure Land was designed specifically to enable students belonging to the experimental group to progress from lower-level to higher-level learning outcomes (from Grades 1 to 4) on the topic Measurements. The control group students were taught through workbooks covering the same learning outcomes from lower grades to higher grades on the same topic.

Only Grade 1 pupils were selected for this study; they had no prior formal knowledge of measurements. They were also unfamiliar with the keywords or terminologies used in measurements, such as comparing heights and weights (e.g., big, bigger, biggest; short, shorter, shortest, etc.).

The data revealed interesting results. Progress was noticed in both the experimental and control group students. Achievement of higher-level learning outcomes was then compared before and after the intervention.

The comparison of pre- and post-test results of the experimental and control groups revealed an overall increase in the percentage scores achieved in higher-level learning outcomes by the experimental group students. Interestingly, the experimental group students were underperforming a little on the achievement of higher-level learning outcomes when compared with control group students (Table 12).

Table 12. Comparison of Higher-Level Learning Achievement Between Groups

	Experimental Group	Control Group
Pretest	53%	58%
Post-test	83.9%	72.4%

The experimental group scored 53% in the pretest, as opposed to the control group that scored 58%. However, after the intervention, although both groups showed improvement, the experimental group performed much better than the control group (Figure 2).

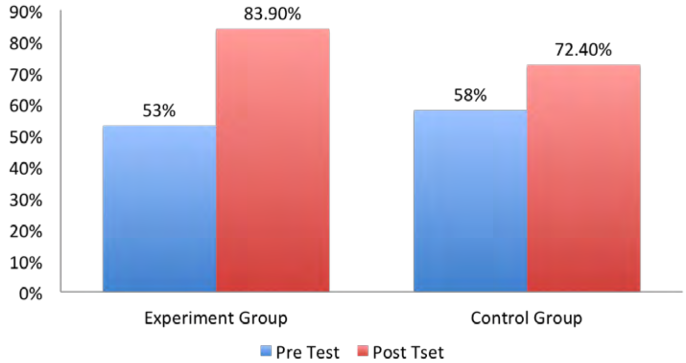

Figure 2. Comparison of Achievement on Higher-Level Learning Outcomes

Figure 3 reveals an overall increment of 58.3% between the scores of the experimental group on the achievement of higher-level learning outcomes before and after the intervention. Similarly, the control group showed a 24.8% increase in the achievement of higher-level learning outcomes.

In a nutshell, after the intervention, an overall increase of 15.9% was noticed between post-test scores of the experimental group as compared with the control group. This large percentage increase in the scores indicates that self-paced learning may be achieved through DGBL without the need of an instructor if, first, the games are pedagogically designed based on the principle of scaffolding learning, and, second, students receive clear instructions and demonstrations so they can grasp the concept before attempting to play at a certain game level.

The design of the learning game had a concept of constructivist learning theory embedded in it. The game supported experiential learning that helped students learn the concept of measurement through their experience in daily life. The activities in the game were designed in such a way that students could apply the concepts learned in their daily life.

The experimental group had no instructors. Even so, the students demonstrated a noticeable improvement in the post-test scores. The instructional design of the game and interactive activities enabled them to use the game on their own without any assistance.

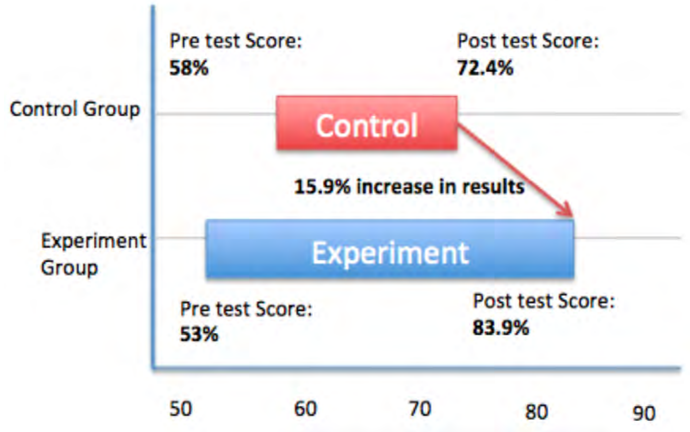

Figure 3. Difference in Achievement Between Experimental and Control Groups

The bilingual instructions helped the students not only understand the content of the game well but also learn new words in English, thus building their English vocabulary.

Figure 4 presents a comparison of individual student scores on pre- and post-tests. The correlation between the scores suggests that almost every student in the experimental group made some progress through DGBL.

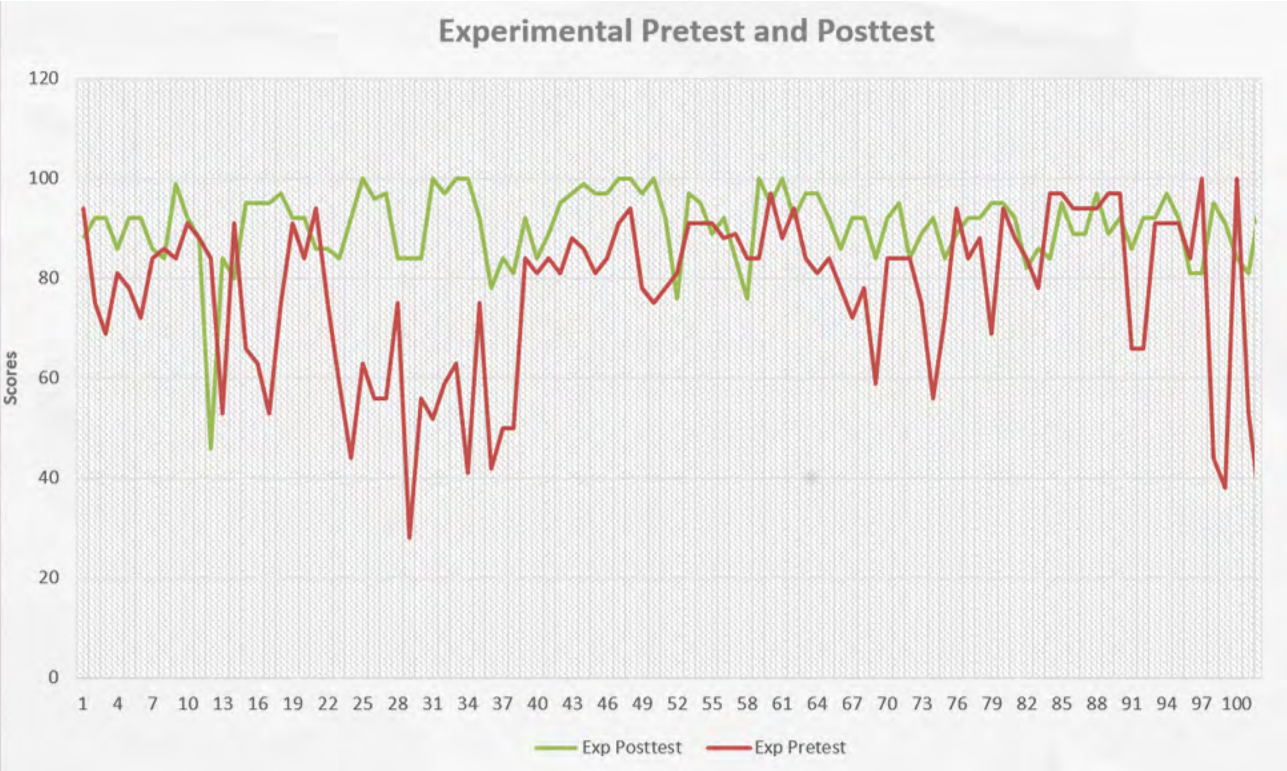

Figure 4. Individual Student Performance in Experimental Group

5.2 Measuring Student Engagement

The BOSS tool was used to measure student engagement, operationalized as PET and AET. Table 13 presents examples of PET and AET. Observers referred to these examples while coding the data in the BOSS application.

Table 13. Examples of PET and AET

Passive Engaged Time (PET)	Active Engaged Time (PET)
• Reading material silently • Listening to the teacher's lecture • Listening to the game instruction • Looking at the board when teacher teaches • Looking carefully at animation • Listening to peer answering question	• Writing • Reading aloud • Raising a hand • Talking to the teacher • Tapping on an answer • Dragging objects

Prior to data coding on the BOSS application, student demographics were keyed in. The duration of each observed activity was set at 40 minutes split into 15-second intervals.

All statistical analyses were performed using IBM SPSS for Windows, with 0.05 as the level of statistical significance for accepting or rejecting a hypothesis.

5.2.1 Testing normality and homogeneity

As with the student achievement scores described in the previous section, PET and AET data were tested for normality of distribution using the Kolmogorov- Smirnov and Shapiro-Wilk tests, and for homogeneity of variance using Levene's test.

Table 14 shows that AET data from the control group are not normally distributed, $D(100) = .128$, $p < 0.05$, while data from the experimental group seem to be normally distributed, $D(100) = .047$, $p > 0.05$. In cases where groups have different distributions, a non-parametric test may be applied.

Since both normality tests yielded significant results ($p < 0.05$), AET data are confirmed to be not normally distributed. Likewise, normality testing confirms that PET data are not normally distributed, with both tests yielding significant results ($p < 0.05$) (Table 15). Thus, a non-parametric Mann-Whitney U test may be used on both AET scores and PET scores to compare mean ranks rather than medians (Field, 2009).

On the other hand, the results of Levene's test, shown in Table 16 for AET data and in Table 17 for PET data, confirm no homogeneity of variance in either data set (AET: $F = 110.759$, $p < 0.05$; PET: $F = 58.018$, $p < 0.05$), thus allowing for the use of the Mann-Whitney U test.

Table 14. Normality Tests on AET Data

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Means of AET	Control Group	0.128	100	0.000	0.935	100	0.000
	Experiment Group	0.047	100	0.200*	0.990	100	0.659

[a] Lilliefors Significance Correction
* This is a lower bound of true significance

Table 15. Normality Tests on PET Data

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Means of PET	Control Group	0.092	100	0.037	0.957	100	0.002
	Experiment Group	0.102	100	0.012	0.975	100	0.049

Table 16. Levene's Test for Equality of Variances (AET Data)

		Levene's Test for Equality of Variance	
		F	Sig.
Means of AET	Equal variances assumed	110.76	0.000
	Equal variances not assumed		

Table 17. Levene's Test for Equality of Variances (PET Data)

		Levene's Test for Equality of Variance	
		F	Sig.
Means of PET	Equal variances assumed	58.018	0.000
	Equal variances not assumed		

5.2.2 Comparison of AET and PET Between Groups

A statistically significant difference between the experimental group and the control group was found in terms of both AET and PET. As Figure 5 shows, the experimental group had more AET than the control group while the control group had more PET than the experimental group.

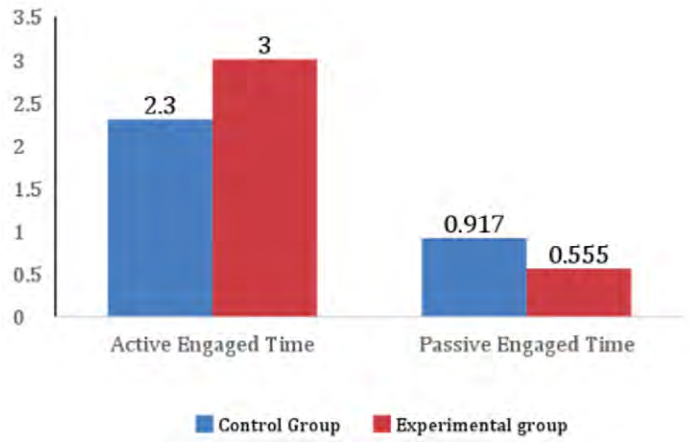

Figure 5. Comparison of AET and PET scores

5.2.2.1 Active engaged time. Mean AET scores were found to be higher in the experimental group (M = 3.114, SD = 0.3459) than in the control group (M = 2.286, SD = 0.8869) (Table 18). Individuals in the control group were found to have AET scores ranging from 0.7 to 3.9 while individuals in the experimental group were found to have AET scores ranging from 2.3 to 3.9.

[a] Lilliefors Significance Correction

A Mann-Whitney U test was carried out on AET. The control group was found to have a mean rank of 73.14 (N = 100) while the experimental group was found to have a mean rank of 127.87 (N = 100) (Table 19). The difference in mean ranks is statistically significant (*U* = 2263, p, 0.05) (Table 20).

Table 18. Mean AET Scores

Group	Mean	N	Std. Deviation	Minimum	Maximum
Control Group	2.286	100	0.8869	0.7	3.9
Experiment Group	3.114	100	0.3459	2.3	3.9

Table 19. Mean Ranks for Mann-Whitney U Test (AET Data)

	Group	N	Mean Rank	Sum of Ranks
Means of AET	Control	100	73.14	7313.00
	Experiment	100	127.87	12786.00
	Total	200		

Table 20. Significance and Statistics for Mann-Whitney U test (AET Scores)

	Pretest Scores
Mann-Whitney U	2263.500
Wilcoxon W	7313.500
Z	-6.687
Asymp. Sig. (2-tailed)	0.001
a. Grouping Variable: Group	

5.2.2.2 Passive Engaged Time. Mean PET scores were found to be higher in the control group (M = 0.919, SD = 0.4761) than in the experimental group (M = 0.542, SD = 0.2304). Individuals in the control group had PET scores ranging from 0.1 to 1.9, whereas individuals in the experimental group had PET scores ranging from 0.1 to 1.0 (Table 21).

Table 21. Mean PET Scores

Group	Mean	N	Std. Deviation	Minimum	Maximum
Control Group	0.919	100	0.4761	0.1	1.9
Experiment Group	0.542	100	0.2304	0.1	1.0

A Mann-Whitney U test was also carried out on PET scores to compare the mean ranks of the control and experimental groups. The control group was found to have a mean rank of 123.47 (N = 100) while the experimental group a mean rank of 77.54 (N = 100) (Table 22). The difference in mean ranks is statistically significant ($U = 2703.5$, $p < .05$) (Table 23).

Table 22. Mean Ranks for Mann-Whitney U Test (PET Data)

	Group	N	Mean Rank	Sum of Ranks
Means of AET	Control	100	123.47	12346.50
	Experiment	100	77.54	7753.50
	Total	200		

Table 23. Significance and Statistics for Mann-Whitney U test (PET Scores)

	Pretest Scores
Mann-Whitney U	2703.500
Wilcoxon W	7753.500
Z	-5.612
Asymp. Sig. (2-tailed)	0.000
a. Grouping Variable: Group	

5.3 Measuring Student Motivation

Descriptive statistics on mean scores of IMMS were conducted on the subscales of attention, relevance, confidence, satisfaction, and the combined Total Motivation Score (TMS).

Figure 6 illustrates that mean scores on all the subscales were higher in the experimental group than in the control group. Consequently, the overall mean scores for motivation were higher in the experimental group (M = 129.73, SD = 13.806) than in the control group (M = 125.99, SD = 19.094). Control group scores ranged from 84 to 176, whereas experimental group scores ranged from 98 to 155 (Table 24).

Figure 7 suggests that the educational games used seem to be more pedagogically effective and motivationally interesting for the children. The students were more attentive, satisfied, and confident when learning through digital games, compared with those who used paper-based text material.

Positive retention of students was also observed because of the motivating, engaging, and entertaining nature of game-based learning courses. Students tended to attend sessions regularly and avoid skipping sessions during the intervention period.

Further analysis was performed to investigate the significant difference between the motivation of the control and experimental group students.

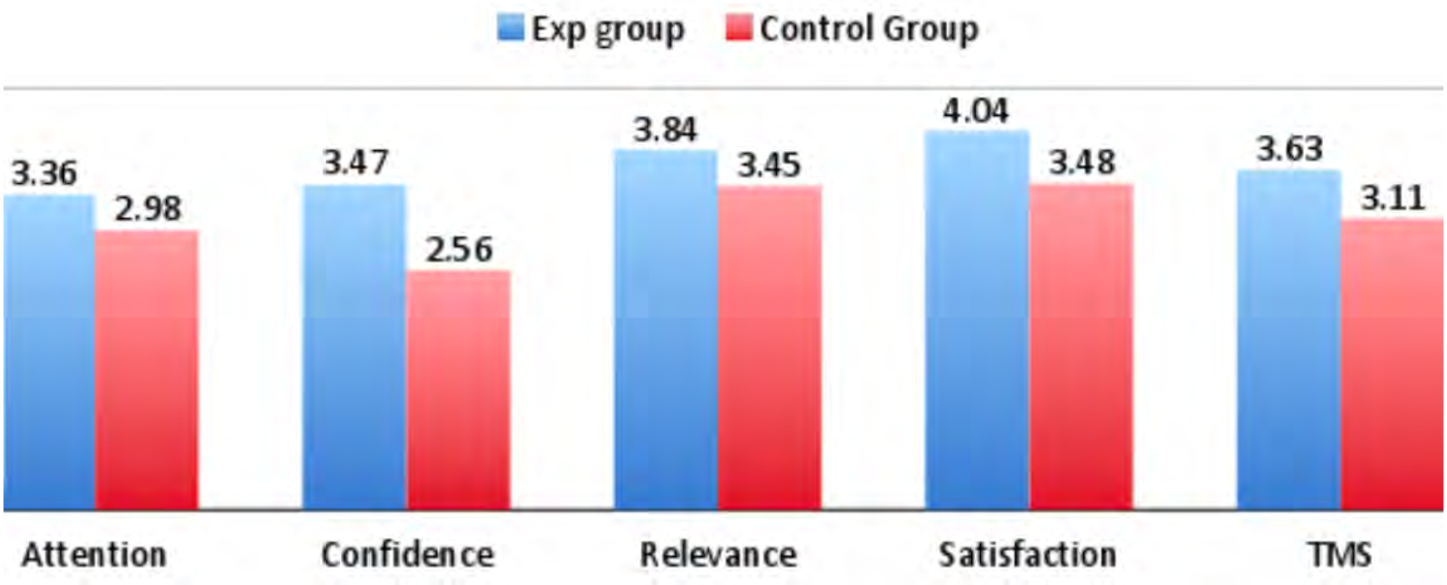

Figure 6. Comparison of Motivation Between Experimental and Control Groups

Table 24. Mean Total IMMS Scores

Group	Mean	N	Std. Deviation	Minimum	Maximum	Range
Control Group	125.99	100	19.094	84	176	92
Experiment Group	129.73	100	13.806	98	155	57
Total	127.86	200	16.725	84	176	92

Since neither the Shapiro-Wilk test nor the Kolmogorov-Smirnov test has significant results ($p > 0.05$), data were assumed to be not normally distributed (Table 25).

Thus, Mann-Whitney's test was performed on the TMS of the control and experimental groups. The control group was found to have a mean rank of 93.75 (N = 100), while the experimental group had a mean rank of 107.26 (N = 1) (Table 26). This analysis was found to have no statistical significance, *U* = 4324.5.5, $p = 0.099$ ($p > 0.05$), which means there is no significant difference in the TMS of the students taught using traditional methods and those taught with game-based methods (Table 27).

No statistical difference was found in the motivation of both groups before and after the intervention. The reason could be the fact that the control group was also involved in active learning by physically measuring objects in and out of classrooms, which may have boosted their motivation. Also, the instructional material provided to them was fairly interactive in nature; it included activities rather than large pieces of text.

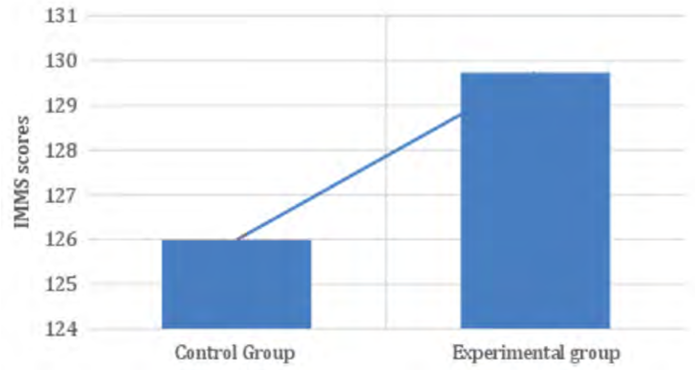

Figure 7. Comparison of Mean IMMS Scores of Experimental and Control Groups

Table 25. Normality Test for Motivational Survey

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Total Score	0.066	200	0.034	0.983	200	0.016

Table 26. Mean Ranks for Motivational Survey

	Group	N	Mean Rank	Sum of Ranks
Total Score	Control	100	93.75	9374.50
	Experiment	100	107.26	10725.50
	Total	200		

Table 27. Significance and Statistics for Mann-Whitney U test (Motivational Survey)

	Pretest Scores
Mann-Whitney U	4324.500
Wilcoxon W	9374.500
Z	-1.651
Asymp. Sig. (2-tailed)	0.099
a. Grouping Variable: Group	

[a] Lilliefors Significance Correction

5.3.1 Learning Beliefs

Game-based learning highly motivated the learners. The engaging features of the game attracted learners' attention and kept them focused on meeting desired learning outcomes. A change in the approach towards math learning was observed. The study found that 65% of the students supported active learning through digital games without the need of the teacher, as opposed to 35% who liked to be taught by the teachers. The results of the baseline survey on conceptions and approaches to learning math also reveal that students who possessed either intrinsic or extrinsic motivation were more likely to adopt active learning strategies than those who had no motivation towards learning and were more inclined to passive learning activities such as rote memorization or listening to the teacher's lecture. The latter were also unable to relate their learning to real-world scenarios. Such children could be at risk of dropping out.

5.4 Teachers' and Students' Perceptions

The research question on teachers' perception regarding the use of tablets as an acceptable option in the classroom compared with traditional techniques of learning mathematics was informed through qualitative data obtained from semi-structured in-depth interviews of teachers and head teachers, and from the FGDs held with students.

Eleven teachers and four head teachers from the selected schools participated in the interviews. Most of the teachers possessed bachelor-level qualification. A couple of them had a master's degree in Education, but neither of them attended formal pre-service teacher training. Nevertheless, they had the opportunity to attend in-service training offered by the school, mainly focusing on lesson planning and curriculum development. It was interesting to note that none of these teachers had used technology in classrooms before, and they possessed very limited computer skills.

In addition to interviews with teachers and head teachers, FGDs with a group of six to eight students were held to understand the usability and effectiveness of game-based learning in classrooms. The interview and FGD responses were translated verbatim and grouped under emerging themes as discussed below.

5.4.1 Concept Building through Digital Games

All of the teachers agreed that digital games with a clear pedagogy help in building student concepts. They all were of the view that interactive elements involving students in meaningful decision-making, animations or videos demonstrating a phenomenon, along with bilingual instructions, help develop students' concepts and address any misconceptions. Moreover, attractive and catchy images, especially if done in a cultural context, improve student attention and engagement for a longer period.

Teachers agreed that the game used for this intervention retained students' attention longer than a traditional classroom setting would. The students not only learned the concept of measurements taught through the game, but the theme setting of different game levels such as a beach, farm, funfair, rockets, post office, etc., also contributed to the imagination of these children, who have never been to such places. This concept-building and imagination would never be made possible in conventional classroom settings because of limited access to resources and lack of time.

Since the game was built on a constructivist learning approach and experiential learning, the students also agreed that the use of real-life scenarios in the game helped them understand the concept in more detail and relate the concepts to real life.

> "I didn't know I could use my arm or anything for measuring. I got so many ideas, I went home and measured so many things," said one student.

"Interactive elements that involve students in a meaningful decision-making, animations or video demonstrating a phenomenon, along with bilingual instructions help developing students' concepts and address any misconceptions."

Both teachers and students were of the view that such games with more challenges and game levels should be extended to other math concepts and other subjects like literacy, science, and geography as well.

Interview data from the head teachers revealed a few concerns. The head teachers believed that using tablets or mobile devices may be an effective medium for teaching provided students are being monitored for what they are playing. Besides, students may not be allowed to take tablets home; the financial situation of the parents might entice them to sell the tablet. However, the head teachers all agreed that access to such devices at home may improve student learning.

Overall, teachers, head teachers, and students all gave positive feedback on the use of DGBL, especially if it embeds a sound pedagogical model to achieve learning.

5.4.2 Age-Appropriate Language

The students came from various backgrounds and were not exposed to English in their day-to-day lives. Although the school textbooks were mainly in English, the teachers used bilingual instructions in class and sometimes translated the content word for word to enable the students to understand the content. Since English was not taught as a second language in schools, it was being offered as a subject. Teachers and students alike were compelled to memorize the book content without developing any understanding of the concepts.

According to the teachers and students, the use of bilingual game instructions and feedback helped the students improve their vocabulary. The students started using words or terms from the game, such as big, heavy, or small, in normal classroom sessions.

The choice of words and pace of audio instructions were also appropriate for students 9 to 15 years old. Moreover, the brief demo and the practice exercises before the beginning of the game were reported to be a good feature that enabled listening and observing skills.

Initially, the students were not in the habit of small practice exercises on how to use the game, which was also very helpful as few students did not listen to instructions because they were not used to this type of instruction.

5.4.3 Embedded Assessments, Feedback, and Rewards

Majority of the teachers believed that the elements of gamification such as collecting stars as rewards and instant feedback increased students' self-confidence and motivated them to move forward in the game. The idea of collecting as many gold stars as possible pushed them to finish the game. The gold stars were equivalent to maximum points in the game. If students received a red star, they tried to figure out their mistake through the feedback given and put effort towards getting the gold star. Teachers agreed that difficult and boring concepts in which students can easily lose interest could be taught with the help of interactive games. A common attribute all children liked was the greater interactivity and immediate feedback from the activities.

Moreover, the students said they would continue to play a level until they achieved all gold stars for that level, suggesting they would master the content of that particular level before moving to the next. Students also liked being encouraged by motivating words in the game —e.g., "well done," "good job," and "excellent"—something that did not happen often in their classroom, and not for everyone. Following are a few of the students' responses:

> "I like how something so fun happens when I answer the question right."
>
> "It's fun because the cartoons tell me if I'm doing anything wrong."

5.4.4 Self-Paced Learning

The students' big age range and varied prior experiences make it difficult for teachers to cater to their individual needs, given the limited class time.

The teachers thought that the instructional design of the game Measure Land contributed to students' self-learning: students would know what objectives they had to achieve after completing a particular level and how the knowledge gained at that level would be applied to the next level. Moreover, the game characters narrating the instructions provided suitable guidance and background information to the students so they would learn the topic and play related practice activities. This setup would allow the teachers to facilitate the class and concentrate on struggling students, while the rest of the class would learn at their own pace with minimum teacher intervention.

This game was also reported as the most suitable medium to facilitate fast-track learning. The student learning outcomes on the topic of measurements from the National Curriculum were arranged in different game levels that allowed the students to master the concept of measurements by just playing the game on tablets, which eventually saved time and avoided unnecessary repetition. Another important feature described by the teachers was the provision of constant practicing of concepts by playing games as many times as the students would like. This would be completely impossible to implement if traditional teaching styles were followed.

Some of the students' responses highlighted the fact that they wanted to be in control of their own learning without the involvement of the teacher. They liked collaborating with their peers and helping each other reach higher game levels.

> "It was fun because my teacher didn't come and force me to do work. I played games, and she didn't stop me."

> "Ali and I were seeing who wins first – I always finished it before him."

> "Ayesha didn't know how to do it, so I helped her."

The students were likewise happy and enthusiastic to experience a new form of learning, and to be allowed to make mistakes and observe patterns without getting worried about being told off by the teacher. They found it refreshing and innovative.

> "I hated writing with a pencil. Playing games is so much fun and a better way of learning."

5.4.5 Management and Logistical Issues

The findings of the interviews with the teachers and head teachers highlighted a concern regarding the logistical issues of tablets and their optimal use in the schools. All of the head teachers were of the view that the limited ICT skills of teachers might be a hindrance in implementing DGBL in schools. Lack of curricular mapped bilingual content may also pose another barrier to the integration of such technologies in classrooms. It is therefore imperative to empower teachers to develop ICT pedagogies, which may motivate them to adopt such pedagogies in their classrooms. New game content aligned with curriculum outcomes must also be developed before the deployment of DGBL models in schools.

Security, storage, technical support, and Internet availability in schools were a few more serious concerns that, if not addressed in a timely manner, may lead to the failure of ICT adoption, especially DGBL, through mobile technologies in schools. The tablets were not school property; the project teams brought them in for the period of research interventions and took them back after project completion. Schools have no access to such gadgets, which would allow teachers to explore and practice the available content during lesson planning. Lack of access in turn demotivates teachers and restricts them from adopting new ICT-intensive pedagogies. Non-availability of the Internet and disrupted power supplies (electricity load shedding) in schools is another major deterrent to using ICT in schools. The tablets need regular charging and updates to avoid hassles and time wasted in class. Based on these concerns, the head teachers and teachers both stipulated having, first, access to tablets and the Internet, and second, the establishment of an IT department in schools to provide regular technical support.

VI. IMPLICATIONS AND RECOMMENDATIONS

A number of recommendations emerged from the key findings to inform further research, policy, and practice, especially in developing countries.

Recommendation 1: Creating long-term effects of DGBL on motivation and engagement

One major limitation of the study was the short period of intervention, spanning only over two weeks in each school. A two-week timeframe may be suitable for learning just one topic from the curriculum, but the possibility of sustained engagement and motivation for longer periods of intervention cannot be ruled out. There is a chance that students were never exposed to such an educational model, which resulted in temporary engagement and motivation. Hence, it is important to plan further research studies that last an entire school semester, if not the whole year, covering the learning outcomes to be taught during that timeframe. Such studies will provide realistic insights into the sustained motivation and engagement of students in their learning process, leading to attainment levels.

Relevant content required to teach through digital games should have been developed and tested prior to the research to avoid any roadblocks during the intervention process. Because of prior non-availability of the digital content, teachers may be compelled to adopt traditional strategies, which may jeopardize the research design.

Another issue that most of the researchers face is access to schools for longer periods. Head teachers normally prohibit long-term intervention as it might conflict with their routine teaching practices. Research to develop new educational models is a combined effort of all stakeholders, including researchers, educationists, developers, students, and governments. School administration should be consulted and informed about the research methodology and the support required in terms of commitment and time management prior to planning the research. Whole school-year intervention must be planned after successful pilot studies and consideration, given the curriculum to be covered in the prescribed timeframe, to avoid students' loss of time.

Recommendation 2: Provision of technical support in schools

The research conducted in schools used project resources such as tablets and digital cameras for recording, as well as human resources to facilitate students in the experimental group and handle any technical issues. The students had access to the tablets only during the intervention sessions; they were prohibited from taking the tablets home. Similarly, the teachers could access the tablets during the school hours restricted to the intervention phase.

To have sustained effects from DGBL, schools should have access to tablets and IT support all the time. Access to free high-speed Internet must be provided to schools so as to optimally use the digital resources. An IT support department must be established in schools to ensure data security, restriction to inappropriate sites for children, and continued technical support for tablet-handling and required updates.

Recommendation 3: Content development informed by cultural and social factors based on pedagogical models to impart fast-track learning

Recent advancements in promoting the use of technologies in schools, particularly in developing countries like Pakistan, focus more on supplying hardware infrastructure. Although the hardware is necessary, so is the relevant content to run on that hardware.

The game industry is booming in Pakistan, but it focuses more on entertainment rather than edutainment. Nonetheless, more relevant and pedagogically sound digital games set in a social and cultural context can be developed to run on low-cost mobile devices. The Ministry of Education or the relevant education department of each district should purchase yearly subscription to such games and allow free access to teachers and students.

Such a sustainable model should work for the game industry and for schools without compromising on access and quality.

Having access to suitable digital content in a cultural and social context may give rise to innovative models of learning such as DGBL modules for children which may prove to be more engaging, motivating, and based on pedagogically informed instructional strategies.

Recommendation 4: Creating master trainer programs for DGBL and ICT integration

There is a considerable dearth of teacher skills and competency to use ICT and digital games within the curriculum. Most of the teachers are not formally ICT-literate or trained to adopt ICT-intensive pedagogies in classrooms. Even when they are pressured by the management to use technology in classrooms, the most they would do is show a video or a PowerPoint presentation, which would have again a passive “chalk and talk” effect on learning.

Teacher training workshops on DGBL should be arranged with a focus of selecting and mapping game content with areas of the curriculum. An efficient and cost-effective approach would be to adopt a master teacher-training model, which would first train and certify several teachers from each school who would later train other teachers in that school. Universities can play a major role in arranging such workshops for teachers. One such university is NUST in Islamabad, where students of the Department of Innovative Technologies in Learning (formerly Innovative Technologies in Education) are trained to train teachers on game-based learning pedagogies to promote active learning through the innovative game-based educational model.

Recommendation 5: Creating a central repository of DGBL resources and a support network for teachers

Capacity building of teachers and empowering them to use innovative technologies in teaching may be one aspect of professional development. However, continuous and ongoing support is a sustainable feature that will motivate teachers to further enhance their skills and seek answers to their queries. A central repository of educational games in the context of curriculum requirements may be established with the collaboration of universities, the game industry, and educationists.

Pedagogues and university students may develop the research-based game prototypes and conduct usability testing, while the game industry could design and market the full-fledged games based on research-based prototypes.

Recommendation 6: Need for a strategic view towards making proactive policies and strategies to enhance digital game-based learning

The government’s policy and strategy for DGBL have important implications for the development of innovative sustainable education models. The government should develop a digital learning strategy and allocate funds to implement the action plans. The international donors or agencies that have technical capacity must assist in the development of these digital learning strategic plans, if required.

VII. CONCLUSION

The aim of this research was to examine the impact of digital game-based learning using tablets on student achievement, engagement, and motivation as compared to traditional classroom instruction in primary school among students belonging to low-income group families in Pakistan.

The findings of this study revealed remarkable results on achievement data of the experimental group of students exposed to DGBL, compared with the control group taught through traditional instructional methods. A large effect size (d = 0.9) suggests that such an impact would have been impossible without selecting the game with a sound pedagogy. Hence, it may be inferred that positive results on student achievement could not be possible by playing just any game, but games with pedagogically sound instructional design, bilingual instructions and graphics, and characters placed in a cultural context.

The evidence from the literature suggests that standardized tests produce more accurate achievement levels than the pre- and post-test instruments developed by researchers for the sake of research. This study employed pre- and post-test instruments based on standardized examinations, which further strengthen the authentication of the achievement data.

Another major finding, which is in line with the previous literature, was the statistically significant difference between the active engaged time versus passive engaged time of students belonging to the experimental group when compared to the control group.

It can be argued that game-based learning was highly engaging, as the students were actively involved in the game-based activities designed for the lesson. Findings from the observation data also showed positive responses of the experimental group students through their facial expressions and posture. The students' constant visual fixation to the tablet screens and interaction with the game content showed that they were highly engaged and enjoying the experience imparted through game-based learning.

Students' vocabulary was also seen to be improving, as they were learning new words and terminologies related to measurements. The teachers likewise agreed that this medium of teaching could be helpful in teaching multiple concepts or languages at the same time. Students were observed to play the game repeatedly and correct previous mistakes made to collect more game rewards. Math teachers believe that practice is the important key factor to achieve success in mathematics (Ghousseini & Herbst, 2016), and the students in this study were seen practicing math problems on their own by playing different levels of the game repeatedly.

Previous literature on game-based learning also supports the notion that games have the power to develop necessary knowledge and skills among students so they can become active participants in a classroom environment (Gözütok, 2000). The game used for this study was designed with a student-centered approach, which enabled students to learn by doing, and fostered peer collaboration in applying concepts of measurements in daily life.

Contrary to these results, the major revelation made by this research was there was no statistically significant difference between the motivation levels of students playing games in the experimental group and students learning through activity books in traditional classroom style. These findings contradict most of the previous research that shows high student motivation through game-based learning. The present study compared the experimental group against the control group, who was also involved in activity-based learning through workbooks. The instructional design of these workbooks, along with teacher strategies, may be a major factor in raising student motivation to interact with the instructional material. Although there was no statistical difference in motivation, scores on a motivational survey of the experimental group were consistently higher than those of the control group. This indicates that motivation is dependent on the instructional design of the learning material, be it a game, a paper-based activity, or simply a textbook. The major factors determining the motivation level are attention, relevance, confidence, and satisfaction. Any learning material that carefully embedded these factors may improve student motivation, which would ultimately increase achievement. The results of the baseline survey on conceptions and approaches to learning mathematics also yielded the same relationship between approaches and conception of learning math. More active learning approaches improve motivation, which helps build better concepts, resulting in better achievement.

The study also identified the possibility of self-paced learning by students through digital games developed on sound pedagogical models. The qualitative data obtained from teachers and students illustrate that the game Measure Land followed a good pedagogical model that would allow students to be in charge of their own learning and explore the content at their own pace; therefore, teacher presence may not be necessary to explain the learning concepts. Hence, games developed with a concept of self-paced learning may be useful for practicing the learning content at home, provided students have access to tablets and the Internet. Moreover, the self-paced nature of the game would allow teachers to concentrate more on struggling students while the high achievers could continue to learn without disruption. The teachers' varied skills make it difficult to implement ICT-intensive pedagogies uniformly in all classes. Therefore, games with sound pedagogy would also address the issue of teacher proficiency in ICT skills, as teachers would just have to manage and facilitate the students, while learning would happen through digital games.

Although the teacher's presence in the class cannot be undermined, DGBL argues for a paradigm shift in the role of the teacher in the classroom. Teachers would require necessary training in order to implement this system in their classrooms. They should be able to make an informed selection of games to be used with the students.

These research findings add to the growing body of literature on the adoption of DGBL as a pedagogical tool for learning. Besides showing the positive impact of digital games on learning, it also supplies evidence on how the socioeconomic context in which people live can support positive use of technological innovation. However, further qualitative research is required to establish the impact of digital games on the personal and social development of people belonging to low, socioeconomic, and culturally diverse populations, and how social, cultural, and economic factors influence students' and teachers' attitudes towards the uptake of digital games for learning in increasingly varied multicultural environments.

"These research findings add to the growing body of literature on the adoption of DGBL as a pedagogical tool for learning. Besides showing the positive impact of digital games on learning, it also supplies evidence on how the socioeconomic context in which people live can support positive use of technological innovation."

VIII. PROJECT INFORMATION AND OUTPUTS

This includes information such as a project website, journal publications, conference proceedings, etc.

Project Website

The project website can be accessed from http://ite.seecs.nust.edu.pk/root/?page_id=4904. The website imparts information about the project and the events that were organized during the project period.

Blog Posts

Two blogs have been written and posted on the following links:

1. Title: Gamifying Mathematical Education to Foster Flexible Learning in Out-of-School Children of Pakistan (http://ite.seecs.nust.edu.pk/root/?p=5048)

2. Title: Impact of Instructional Designing for Enhancing Students' Motivation in Digital Game-Based Learning (http://ite.seecs.nust.edu.pk/root/?p=5055).

Conferences/Presentations

To share the results with the key stakeholders, an open house on DGBL was held on 20 December 2016. A wide range of stakeholders from all over Pakistan, including teachers, practitioners, instructional designers, game designers, game developers, researchers, civil organizations working towards quality education, officials and policymakers from the Ministry of Education, as well as NUST students, attended the event.

Key findings were shared with the audience, leading to a panel discussion on the adoption of game-based learning in schools and the associated challenges. The panel, composed of a variety of professionals belonging to the Ministry of Education, not-for-profit organizations, and some of the leading universities in Islamabad, tackled the pros and cons of using tablet technology in primary schools. The discussion concluded on the note that localized, cross-platform, digital content based on sound pedagogical models must be developed to integrate DGBL in schools. Another major outcome of the discussion was the need for capacity building of teachers on adopting ICT-intensive pedagogies, where NUST can collaborate with the Federal Education Directorate in organizing teacher-training workshops.

Towards the end of the open house, Dr. Haroona Jatoi, the advisor to the Education Minister, shared that the Federal Ministry of Education is forming a new policy that would incorporate innovative teaching methods such as game-based learning into schools. She promised to convey the results of the project and panel discussion with the concerned authorities in the Ministry of Education to inform future policy on innovation in teaching and learning.

Planned Publications

The following papers have been drafted for open access in two identified journals:

- British Journal of Educational Technology
- Journal of Science Education and Technology

The first paper reports the overall result and the insights from the project activities. This paper is titled Impact of Digital Game-Based Learning on Achievement, Motivation, and Engagement in Out-of-School Children in Pakistan.

The second drafted paper discusses the motivational effect of instructional designing for DGBL. The title of this paper is Examining the Motivational Effect of Instructional Designing for Digital Game-Based Learning for Out-of-School Children in Pakistan.

The third draft paper reports the conceptions of and approaches to learning mathematics. The working title of this draft paper is Exploring Out-of-School Children's Conceptions of and Approaches to Learning through Exploratory Factor Analysis.

As of this writing, all the aforementioned papers are in draft mode, which requires proofreading and a thorough review by experts. After proofreading, these papers are expected to be available for review by the theme advisors and ready to submit to the identified journals.

Project Showcasing

The project work has been demonstrated at NUST Creative Learning School. Students from Classes 1 to 4 were involved in learning to play the developed game Measure Land. It was interesting to find that the students understood the game mechanics and the concept of measurements without teacher intervention, which further supports the research results on self-paced learning through digital games. As a result, the school administration became interested in using this application in its curriculum to enhance learning. A need analysis was carried out to find the areas where students of NUST Innovative Technologies in Education can add support in developing pedagogically informed applications based on the school's curriculum.

Further Collaboration on Improving Teaching and Learning Quality

Students of the MS in Innovative Technologies in Education planned capacity-building activities to train OSCS teachers in delivering DGBL using tablets to improve the literacy skills of their students. A needs analysis was conducted in March 2017.

Formal capacity-building workshops with teachers of OSCSs was initiated in April 2017. Baseline data on students' reading skills were collected using the Early Grade Reading Assessment (EGRA) tool initially developed by the U. S. Agency for International Development to evaluate the existing reading skills of target students. Teachers were also trained in using the EGRA tool to monitor the reading fluency of the students. Students are now being taught using digital games based on their reading skills. Three months after the completion of the intervention period, a post-test will be done using a similar EGRA tool to review the difference in reading fluency gained through DGBL.

Capacity Building

During the project phase, 10 teachers of OSCSs were trained in the use of game-based learning in classrooms.

Besides this, the project also provided an opportunity to 11 female and five male project team members to increase their research and communication skills. The team members received customized training on data collection procedures, observations, and coding using BOSS instruments, and SPSS for conducting quantitative analysis.

Policy and Practice Events

Based on the project results, future projects and policy and practice recommendations were discussed at the following three events within the last quarter of the project.

1. Meeting with the head of the Planning Commission, Mr. Ahsan Iqbal, on future educational reforms, held in November 2016
2. Meeting with advisors to the Minister of Education, Dr. Haroona Jatoi and Prof. Rafique Tahir
3. Invited talk on DGBL in a symposium hosted by the ICT R&D Fund, Bahria University, Islamabad, Pakistan.

Follow-up meetings are scheduled in the near future to develop further action plans.

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ABOUT THE AUTHORS

Muhammad Muddassir Malik completed his PhD in Scientific Visualization in 2009 from the Institute of Computer Graphics and Algorithms, Vienna University of Technology. The topic of his doctoral dissertation is “Feature Centric Volume Visualization.” During his doctoral studies, he worked on computational and visualization problems of 3D datasets obtained from industrial computed tomography and medical resonance imaging machines. He is currently an assistant professor at the School of Electrical Engineering and Computer Science, National University of Sciences and Technology (NUST-SEECS) in Pakistan, where he also leads a research lab. He has a keen interest in serious games (edutainment) and in the use of visualization as a tool for effective communication.

Farzana Ahmad is an expert in instructional design and effective pedagogy using technology. She is a lecturer on innovative technologies in education at the National University of Sciences and Technology (NUST), Pakistan. Her research focus is to find innovative ways to improve quality and access to learning using low-cost technologies to cater to a vast majority of underprivileged children as well as adults in Pakistan. She is involved in various research projects on digital game-based learning where she provides expertise on developing instructional strategies especially for out-of-school children located in socially marginalized areas. Presently, she is pursuing a doctorate degree from the University of Waikato, New Zealand, in the field of education, with a specific focus on digital game-based learning for literacy skills development in a developing country context.

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Foundation for Information Technology Education and Development, Inc. (FIT-ED)
3/F Orcel II Building, 1611 Quezon Avenue, Quezon City 1104 Philippines
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