TEACHING PHYSICS WITH INTERACTIVE COMPUTER SIMULATION AT SECONDARY LEVEL

Nadia Rehman
Shaanxi Normal University, SNNU
Xian, China
nadiarehman05@outlook.com

Wanlan Zhang
Shaanxi Normal University, SNNU
Xian, China
zhangwelan219@163.com

Amir Mahmood
Xi'an Jiaotong University, XJTU
Xian, China
amirmahmood786@hotmail.com

Faiz Alam
Lahore University of Management Sciences, LUMS
Lahore, Pakistan
faizeaalam@yahoo.com

Abstract. Early research investigated the students understanding of science concepts using physical equipment, such as visiting labs and performing experiments but due to the advancement of new technology, students now can learn complex science concepts through advanced means, such as iPad, smart books and simulations. In Pakistan, interactive computer simulation program is rarely used for teaching at the early ages. The aim of the present study is to evaluate the effectiveness of the interactive computer simulation program PhET to teach weight and mass concepts to high school students. Quasi-experimental design was used to study the effect of the interactive computer simulation on students' physics concepts. Study also explored the student's engagement with simulation to exercise high order thinking skills. The experimental group was taught with the interactive computer simulation program, and the control group was taught with traditional teaching method. There were five lessons each week, and the program was used for a month. Pre- and post-tests were designed for both experimental and control groups. Independent sample t-tests showed that the difference was significant between the mean scores of the experimental and control groups after the experiment ($p<0.001$). The paired sample t-test showed that there was a significant difference in the mean scores of pre- and post-test of the experimental group ($p<0.01$). The effect size, 0.97 was also found to determine the magnitude of the difference through Pearson's correlation coefficient r, and a very large effect was identified. Apart from the quantitative data, interviews with teachers and focus group discussions were held to learn the teachers' and students' views. The qualitative data concluded that students showed an interest in using simulation, teachers and students appreciated the simulation program for teaching complex physics concepts. The results provided a case for using Information communication technology to improve students' physics learning. Information communication technology is intended to reduce the culture of rote memorization among students.

Keywords: ICT (information, communication and technology); ICS (interactive computer simulation); PhET (physics Education Technology); high school students; physics learning.

INTRODUCTION

In recent years, technology has been progressively integrated into education and has made significant improvements in the teaching–learning process. Due to the rapid advancement of technology in the education sector, there is inevitable change in the instructional environment of teaching. In education, there is a growing trend toward interpreting information technology (ICT) in the classroom. Great importance has been given to the use of technology to change the classroom environment and provide more accessible resources to the learner (Falloon, 2019). Information technologies help promote opportunities for sharing knowledge throughout the world. Technology helps teachers and students have up-to-date information (Haag & Dawkins, 1998).

Previously students understood science concepts using physical equipment, such as visiting labs and performing experiments; but due to the advancement of technology in the field of education, students now learn science through advanced means, such as iPad, smart books and simulations (Falloon, 2019). These teaching tools are developed and available to facilitate the students' learning (Coffman, 2006). These tools help students promote active and interactive learning environments and also facilitate students to effectively communicate, share information, and exchange ideas and learning experiences. Technology has revolutionized the teaching and learning process. Now web-based instruction is widely used all over the world, and active teaching and learning practices are adopted by many educationists over past many decades. These approaches promote a constructivist thought of learning, in which knowledge is constructed by the learner who is active and reflective (Strayer, 20016). In the era of technology, the education sector has experienced a paradigm shift recently. Classrooms are more student-centered as compared to teacher-centered. The focus is on the construction of knowledge as compared to the transfer of knowledge and rote memorization. Due to this shift, technology has made the teaching and learning process easier, specifically in the field of science. Technology boosts the students' motivation towards learning, and ICT

for instructional purposes has been found to develop self-learning and active learning among students (Li, Sun and Jee, 2019).

INTRODUCTION OF TECHNOLOGY IN PAKISTANI SCHOOLS

In the Pakistani education system, traditional pedagogical techniques are still used in schools and colleges. Students learn largely from extracting knowledge from the textbooks and lectures. All these styles of learning rarely give students the opportunity to apply their newfound knowledge to actual situations; thus, there is a serious time lag between students learning and applying new knowledge. As a result, many students face difficulties in determining the relevance of what they are being taught, and thus teachers lack the motivation to truly engage the students within the learning process (Raymond, 2010).

In Pakistan, the education system is entirely based on rote memorization. Students merely cram the content material in order to get good grades and do not understand the concepts. When these students enter intermediate or higher education, the quality of education is affected. Throughout life, these students failed to apply simple theoretical concepts to "real life" situations (Alfjijam, 2013).

Pakistan needs serious attention toward the integration of ICT into curriculum, which will enable educators to be vigilant in education. ICT can enable the developing countries stay aligned with the developed countries. For a productive and enthusiastic generation, the Pakistani education system should equip students with a variety of ICT tools (Aftab, 2015). In the private sector, technology is used in the teaching and learning process. Thus, the new generation comes ready to work with these new technologies, which play an important role in children's learning and acquiring various cognitive knowledge. The application of educational technology enhances skills and cognitive characteristics. With the help of technology, the process of learning and receiving new information becomes easy and effective (Hussain & Safdar, 2008).

The national education policy (1998-2010) has placed much importance on the quality of education. According to the national professional standards for teachers (2009) by the ministry of education and policy planning, one of the most important standards was the use of ICT (ministry of education, 2009). The government of Punjab has taken several steps to highlight the importance of integration of ICT in the curriculum E-learn. The Punjab (2014) program has provided all the textbooks until the secondary level on websites. Both teachers and students can use these books, which also included some extra information in the form animations, assessments, simulation, and videos.

THE INTERACTIVE COMPUTER SIMULATION PROGRAM

In recent years, interactive computer simulations have been progressively integrated into teaching science subjects and have contributed significant improvements in the teaching–learning process. Interactive computer simulation is a tool that provides realistic experience to the students. Interactive computer simulation provides a great opportunity to the learners to explore the environment that reflects real world situations (Wilson, 2016). Interactive computer simulation provides opportunities to interact with situations that are not possible in real life. It provides a dynamic interactive and visual learning experience (Clark, Nelson & Sengupta 2009). It is helpful for learners to practice problem-based learning through a specific task to experience the situation. As a result, students learn to think critically in a complex situation (Coffman, 2006). Interactive computer simulation is a favorable teaching tool for training the students' ability of integrating theory with practice. It helps the learners combine and deepen their understanding of the theory. Theories originate from practice and are the refinement, abstract, and summary of practice. The penetration of practice will in turn deepen the understanding of theory. In teaching, students get abstract theory, which is hard to make sense of and understand the concepts.

On the other hand, technology makes the learning process more interesting (Alfajjam, 2013). At the international level, interactive computer simulation is widely used in classrooms for concept clarification. Teachers widely use the technology tool in the classrooms to facilitate the students' learning (Coffman, 2006). A couple of studies have found the use of simulations to teach science concepts to primary and secondary-aged students (Kolloffel & de Jong, 2013).

According to Wieman & Perkins (2006), simulations are easy to integrate into a curriculum. Research shows that computer simulations transfer abstract ideas into concrete concepts and improve students' perception, understanding, intentions, and concepts. Generally, "primary school students can benefit from learning (scientific knowledge) through more than one representation" (Wnag & Tseng, 2018, p.2016). Simulations also enhance the cognitive thinking of learners and enable students to relate science concepts

to their real-life experiences. For the science concepts they provide "computer based animations (such as simulation, models & natural experiments) of scientific phenomenon's" (Linn, Chang, Chiu & McElhancy, 2010. P.235). Teaching through simulation has a positive effect on the students' conceptual understanding (Wang, Kinzie, McGuire & Pan 2010).

In Pakistan, there is little research conducted on the use of interactive computer simulation in teaching at the school level. Although there are many research studies conducted on the use of technology in teaching and learning, there is no implication of this research. Computer interactive simulations are dramatically used in science and engineering, but these simulations are not used at the school level. The present study is conducted to fill this gap. This was an experimental research in which the focus was on the implementation of an interactive simulation program for teaching physics concepts. The reason for choosing this idea was that the interactive simulation program is a relatively new concept in Pakistan. No Pakistani literature has been found to support the current study, according to best of the researcher's knowledge. In contrast, the use of an interactive simulation program is appreciated and encouraged all over the world at all levels. The physics subject was selected for the research for two major reasons: First, physics has more abstract concepts that cannot be taught through lab experiments, due to the unavailability of resources and equipment. Secondly, during field work, schoolteachers shared that students face more problems in physics compared to learning concepts of biology and chemistry. The concept of interactive simulation program is now gaining popularity due to its effectiveness for conceptual understanding of complex concepts (Jimoyiannis & Komis, 2000). That's why this idea was chosen for its implementation in the Pakistani context. The interactive simulation program encourages and supports the student-centered approach of constructivism (Agarwal, 2000).

The interactive simulation program provides the opportunity for students to replace the environment by visual interaction. It also involves active participation of students. Students are also responsible for their own learning, which makes them independent learners (Jimoyiannis & Komis, 2000). In contrast, the Pakistani education system is more teacher-centered and uses the lecture method for teaching all subjects. The use of the lecture method promotes the culture of rote memorization among students. Due to rote memorization and cramming practice, the students and teachers do not focus on the conceptual understanding. Keeping in view this situation, such concepts (interactive simulation program) must be encouraged. This will help students understand the complex concepts of the scientific phenomenon in the 21st century web-based simulation education system. The interactive simulation program encourages the students to focus on higher level cognition, such as application, analysis, synthesis, and evaluation. However, in the traditional classroom, students just rely on the knowledge transferred from teachers to students. The interactive simulation program provides the opportunity to carry out the teaching and learning process for the subject of physics keeping Bloom's taxonomy in mind (Alfajjam, 2013).

THEORETICAL FRAMEWORK

The researcher supported the current study through constructivist theory. After reading through the relevant literature, it was noted that much emphasis was placed on different aspects constructivism that provided guidance to be implemented in a simulation class. The constructivists' theory describes the perspective of the learner as they learn from their daily life experiences, observation, and social interaction (Selley, 2013). Constructivist learning theory supports learning through interactive computer simulation program. Computer simulation program, supported by constructivist thoughts, enables learners to interact, create, actively cooperate, and collaborate during knowledge production. Interactive computer simulation program was designed in a way that covered all the proposed aspects of constructivism (Alfajiam, 2013).

The Constructivist Theory of Learning

The researcher focused on the two main contributors of the constructivist theory. Piaget proposed that the cognitive development of the children takes place during the adaption and interaction with the world around them. According to Piaget, the process of learning occurs through assimilation and accommodation during the cognitive developmental stages of the learner (Hasan, 2013). Vygotsky also supported the Piaget theory and further added that the construction of knowledge occurs when the learner interacts with his or her environment within the sociocultural context, for example when the learner interacts with his or her parents, peers, and people who are knowledgeable, have influence, and do dialogue and discussion. The Shayer (2003) mentioned the thoughts of Vygotsky in his work "The instruction given in one area can transform and reorganize other areas of child's thought, it may not only follow maturing or keep in step

with it but also precede it and further its progress. (T&L, p. 177)". According to the Vygotsky most of the time teacher ignore the development stage of the children, not only the physical but mental development of the children and he criticized the direct teaching of concepts, that are fruitless for the students it's more like repetition of the words and transferring a knowledge covering up a vacuum (Shayer,2003).

According to the Shayer (2003), there is a dual relationship between cognitive development and conceptual learning, when the concepts are developed higher level of learning become possible. At school level there is a more demand to re-process the learning in their own unstructured manner and hence receive a motivation to further cognitive development. Therefore, revolutionary teaching method is required to fill this gap. As Vygotsky stated that "Scientific and spontaneous concepts reveal different attitudes toward the object of study and different ways of its representation in the consciousness (T&L, p.161)". computer simulation presents the material in different ways, that helps the students to develop conceptual understanding of the concepts (Alfajjam,2013).

For this study the researcher adopted both Piaget's and Vygotsky's perspectives of constructivist learning theory because they support the concepts of each other in the process of the construction of knowledge. Piaget proposed the two major parts of the cognitive constructivism. The first part is the developmental stage theory, which defined that the learner learns at different stage of the development. The second part is the cognitive ability of the learner to adapt into a new situation, and it involves the process of the assimilation and accommodation (Cobb, 1994).

Conceptual Change Theory

In 1982 Posner proposed the conceptual change theory (CCM). For the present study, the researcher adopted this theory and related it with the interactive computer simulation as a software used to change the misconceptions of the learners as a remedy tool instead of traditional teaching method for teaching physics. According to Posner (1982), every learner has conceptual ecology that can be changed because the learner cannot ask questions about the phenomenon until he or she has some pre-conception about the phenomenon. The present study focusses on the conceptual understanding of physics students from 13 to 15 years old, and it is the last phase of Piaget's perspective of cognitive development. Students in this group mostly move towards the concrete to formal operational stage and mostly face problems with abstract concepts understanding, which are mostly intangible concepts. The traditional teaching methods are not enough to teach intangible and scientific concepts, and students are also not able to get the concepts of scientific problems; for these students need appropriate tools to teach scientific concepts that are mostly not possible in a real-life school situation. Traditional teaching methods promote rote memorization. In rote learning, it is considered that learning is in progress when students retain the concepts and new information of all the subjects and recall them in tests or exams, without modification or understanding or relating it to daily life experiences to have meaningful learning (Ellis & Loveless, 2013).

To overcome the conflict between the preexisting knowledge and new scientific concepts, teachers should revise or modify the preexisting knowledge before transmitting new concepts; this will decrease rote learning in students (Tekos & Solomonidou, 2009). Jimoyiannis and Komis in 2001 conducted research on the use of interactive computer simulation. The researchers concluded that the interactive computer simulation program has the ability to engage students in conceptual understanding of abstract concepts that is not possible with traditional teaching methods. The interactive computer simulation presents the three characteristics of Posner's concepts of intelligibility, plausibility, and fruitfulness in the form of static graphics (photos, maps, or illustrations), animations (as dynamic graphics and video), and words on the screen.

Interactive Simulation Program is relatively a new concept in Pakistan. No Pakistani literature has been found to support the current study. Simulations are dramatically used in science and engineering field but these simulations are not used at school level. The present study is conducted to fill that gap. In contrast, the use of Interactive Simulation Program is appreciated and encouraged in all over the world at all level (Hasan,2013). The concept of Interactive Simulation Program is now gaining the popularity due to its effectiveness for conceptual understanding of complex concepts (Komis, 2000). That's why this idea was chosen for its implementation in the Pakistani context. The Interactive Simulation Program encourages and support the student-centered approach of constructivism of teaching and learning process (Agarwal, 2000). The Interactive Simulation Program provides the opportunity for students to replace the environment by visually interaction. It also involves active participation of students. Students are also responsible for their own learning and makes them independent learner (Jimoyiannis & Komis, 2000).

In contrast, the Pakistani education system is more teachers centered and used lecture method for teaching all subjects. The use of Lecture method instruction promoted the culture of rote memorization among the students. Due to rote memorization and cramming practice the students and as well as teachers do not focus on the conceptual understanding of the students. Keeping in view this situation such concepts (Interactive Simulation Program) must be encouraged. It will help the students to understand the complex concepts of the scientific phenomenon in 21st century web-based simulation education system.

Through Simulation Program students can achieve higher level cognition like application, analysis, synthesis and evaluation. However, in traditional classroom students just rely on the knowledge memorization. For these reasons the following research questions were formulated:

1. What is the difference in the level of students' conceptual understanding of physics concepts taught through interactive computer simulation and taught in a traditional way?
2. What are the students' views about the learning physics concepts using interactive computer simulation?
3. What are the teachers' views about teaching physics using interactive computer simulation?

METHODOLOGY

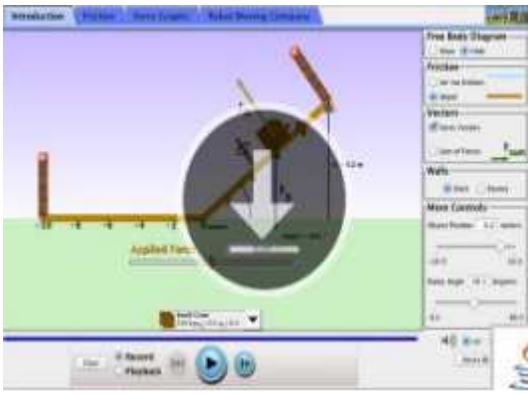
For the current study, the mixed methods approach was used. For that researcher used concurrent embedded design in which qualitative part of the study to complement the quantitative data. Concurrent embedded design is also used to generalize the results of the data on the whole population (Cresswell, 2011). The focus of the study was to check the effectiveness of interactive computer simulation on the students' conceptual understanding as an instructional intervention. For assessing the effects of specific intervention, the quasi-experimental design was used. Targeted schools were neither practical nor feasible to assign the sample randomly to treatments, so pure experimental research could not be possible in real situations. Quasi experimental research is known for non-randomizing intervention study that prevents researchers from creating an artificial setting by randomly assigning participants (Cohen, 2007). The researcher used one of the most commonly used quasi experimental designs in educational research, in that both groups were not selected equally and had not been equated by randomization and were called nonequivalent control group. Non-equivalent control group means that groups are not randomly assigned (Cohen, 2007). To reduce the weaknesses that may result in unreliable findings, different techniques are used in quasi experimental design. Instead of random assignment, other methods can be used for the selection of groups, such as matching techniques. In the present study, groups are selected as equally as possible. The participants of the group are selected on the basis of many of the same characteristics as possible before giving intervention (Shadish, Cook & Campbell, 2002).

For the present study, the experimental and control groups were selected. After matching the different characteristics, both groups were selected from the same institute. The participants of both groups were selected from same grade level, which was 8th grade. Both groups belonged to the science group. The content of the syllabus was same for both the experimental and control group. The conceptual physics test was given to both groups before and after the intervention. The pre-test scores showed an equal level of conceptual understanding of both the experimental and control group. This technique helped the researcher in building confidence on the selection of two groups as equally as possible. Experimental group There were two 8th grade classes; one class was selected as the experimental group who had fewer students as compared to the other class because of the lack of computers. The other class was selected as control group. The selection of the classroom is done by the head of the school. In the experimental group there were 41 students, who used an interactive computer simulation for the learning of physics concepts. In this group the students were facilitated to the computer lab, and students were arranged in a group due to the lack of computers, so that the students in a group could learn the concepts easily through computer simulations. Before intervention, the physics teachers were informed about the intervention. The computer lab assistant also helped the teacher to implement simulation in teaching physics classroom, so the teachers were fully aware and available along with the researcher in both classes to facilitate the students. Each concept was taught and practically performed by the students with the help of simulations. To develop conceptual understanding of the students, class activities were given to the students to calculate the mass or speed with the help of simulation. In each class simulations were used by students (as shown in the table 1) to develop conceptual understanding. Students were asked to solve the problems using simulations e.g. how much

force (F) is needed to apply to move the 5kg box. Simulations helped the students to know the difference between mass and weight and the relation between velocity and acceleration.

THE SIMULATIONS

Table 1. Simulations used by the students to learn Physics concepts.

Relation between force, position and velocity. 	**Description** This was the first simulation presented to students .it defines force as a vector or scalar quantitatity.it also help the students to understand the relation between force, weight mass and velocity. This simulation was selected to give the basic concepts of scalar and vector quantities. Explore the forces at work when pulling against a cart, and pushing a refrigerator, crate, or person. Create an applied force and see how it makes objects move. Change friction and see how it affects the motion of objects. **Sample Learning Goals** • Identify when forces are balanced vs unbalanced. • Determine the sum of forces (net force) on an object with more than one force on it. • Predict the motion of an object with zero net force. • Predict the direction of motion given a combination of forces.
	**Description** Explore the forces at work when you try to push a filing cabinet. Create an applied force and see the resulting friction force and total force acting on the cabinet. Charts show the forces, position, velocity, and acceleration vs. time. View a Free Body Diagram of all the forces (including gravitational and normal forces). **Sample Learning Goals** • Predict, qualitatively, how an external force will affect the speed and direction of an object's motion. • Explain the effects with the help of a free body diagram. • Use free body diagrams to draw position, velocity, acceleration and force graphs and vice versa. • Explain how the graphs relate to one another. • Given a scenario or a graph, sketch all four graphs.
	**Description** Explore forces and motion as you push household objects up and down a ramp. Lower and raise the ramp to see how the angle of inclination affects the parallel forces. Graphs show forces, energy and work. **Sample Learning Goals** • Predict, qualitatively, how an external force will affect the speed and direction of an object's motion. • Explain the effects with the help of a free body diagram. • Use free body diagrams to draw position, velocity, acceleration and force graphs and vice versa. • Explain how the graphs relate to one another. • Given a scenario or a graph, sketch all four graphs. **Topics** • Force • Position • Velocity • Acceleration

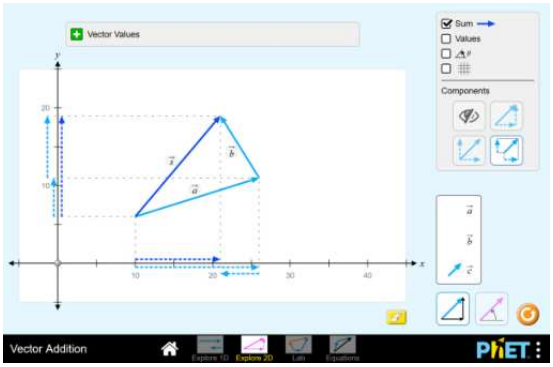


Description

Learn about position, velocity, and acceleration graphs. Move the little man back and forth with the mouse and plot his motion. Set the position, velocity, or acceleration and let the simulation move the man for you.

Sample Learning Goals

- Interpret, predict, and draw charts (position, velocity and acceleration) for common situations.
- Describe his/her reasoning used to make sense of the charts.



Description

Explore vectors in 1D or 2D, and discover how vectors add together. Specify vectors in Cartesian or polar coordinates, and see the magnitude, angle, and components of each vector. Experiment with vector equations and compare vector sums and differences.

Sample Learning Goals

- Describe a vector in your own words
- Explain a method to add vectors
- Compare and contrast the component styles
- Decompose a vector into components
- Describe what happens to a vector when it is multiplied by a scalar
- Arrange vectors graphically to represent vector addition or subtraction

Topics

- Vectors
- Vector Components
- Vector Addition
- Equations

This table demonstrate the number of simulations used by students while learning physics concepts about Mass, Force, vector quantity, scalar quantity and velocity.

CONTROL GROUP

In the control group, there were 45 students. The traditional teaching method (lecture method) was used to teach the same concepts to the students in control group. This is referred to as "traditional teaching." For the selection of the institutes, convenient and purposive sampling technique was used that are a form of non-probability sampling technique. The researcher also conducted the field observation of the targeted population to check the facility of the technology in computer lab. The ages of the participants were between 14 and 16 years old. It was a boys' high school, so the participants of both the experimental and control group were boys. A pretest was given to both the experimental and control groups to check the participants' prior knowledge. After the intervention, a posttest was given to check the conceptual understanding of the students about physics concepts. Purposive sampling technique was used to select the teachers for interviews. According to Marsden, 2004, the teachers of the institute should be involved in the experiment to get their own experience of the intervention. For the current research the coordinator of the school itself and one of the most senior physics teachers were involved in the intervention, and the involved teachers cooperated with the researcher fully. Focus group discussions were conducted from the students of experimental group, who were willing to participate. The Data Collection Tools The data of the study was collected in three different ways:

1. A physics conceptual test, to check the conceptual understanding of the students about the selected physics topics.

2. Focus group discussion to check the students' views about the effectiveness of interactive computer simulation in the teaching and learning process of physics concepts. Focus group discussions were conducted after the intervention for students who were involved in the intervention group.
3. Interviews: physics teachers' views about the use and effectiveness of interactive computer simulation in teaching and learning process of physics concepts.

The physics textbook, published by Caravan Book House, Lahore, revised in the academic year 2015-2016, was selected for the 8th grade students for teaching physics concepts with the help of interactive computer simulation. The test was designed with the full consultation of the professor of the physics department and three physics expert teachers of secondary schools with more than ten-year teaching experience in physics teachers teaching at the secondary level. The researcher designed the test of 20 marks with 20 items in each test, and each question carried equal marks. The test was comprised of multiple-choice items; the simulations were selected according to the selected topics. The researcher consulted two websites for the simulation: PhET simulation software and Interactive Physics Curriculum Simulation. Simulations were selected according to the assigned topics of the physics book (the concept of rest and motion with respect to surrounding, types of motion, the concept of scalar and vector quantities, position, distance, displacement, speed, uniform speed, velocity, uniform velocity and acceleration, graphical analysis of motion, force inertia and momentum, Newton's laws of motion, law of conservation of momentum, and friction). Semi structured interview of teachers. The two physics teachers of the 8th grade class were also the part of the intervention and cooperated with the researcher in the organization and management of the classroom. The conceptual test was also designed with the mutual consensus. To know the participants' story and views behind the experience, interview is very useful tool ((McNamara, 1999). After the intervention, the teachers were interviewed to get their views and ideas about simulation programs in the teaching and learning process. The aim of the interview after the intervention was to consider the physics teachers' observations about the students' involvement during the computer simulation class and their conceptual understanding about physics concepts. The second aim was to determine the externals factors that effected the efficiency of interactive computer simulation and its usability in the classroom. Student focus group discussion. The focus of the third question was to get students' views about their experience of learning physics concepts with interactive computer simulation program. The questions were more subjective in nature and called for a qualitative approach to research. For this research question, focus group discussions were conducted with ten to twelve students in each group. The main purpose of the focus group discussion was to exchange the ideas, views, and experience of the selected group about the treatment or intervention10. For this purpose, the focus group guide was developed by the researcher.

DATA ANALYSIS

Considering the type of the parametric, data t test was applied. For the statistical difference of the two groups, two tests were applied: independent sample t test and paired sample t-test. Pre and posttests were taken from both the experimental and the control group. For the preliminary analysis (See the Table 2) of the pretest scores of the experimental and control group, t-test was applied, and the results are given below to show the equal conceptual understand of the physics concepts.

Table 2. Preliminary analysis of the pretest and posttest mean scores of the experimental and control group

	N	Mean	Std. Deviation
Experimental-pre	41	12.68	4.015
Control-pre	45	11.82	2.605
Experimental-post	41	29.46	5.376
Control-post	45	16.84	3.618

This table demonstrate the pretest and posttest mean scores of experimental and control groups. Means scores shows that there was not significant difference in the mean score of experimental and control group before intervention but after intervention the mean score of experimental groups are higher than control group.

INDEPENDENT SAMPLE T-TEST

To compare the result of the mean scores of the both experimental and control group of parametric data, independent sample t-test was applied. Independent sample t test is widely used in research to find the significant difference in two groups (Cohen and Manion, 2007). Posttests were taken from both the experimental and the control group after intervention, and an independent sample t-test was applied to the data. The results showed that the difference was highly significant between the mean scores (see the Table 3) of the experimental and the control group after the experiment. The significant value is smaller than the p value ($p<0.05$), which indicates the highly significant difference in the post test of the both the experimental and the control group (see table

3). This indicates that the students of the experimental group have a higher conceptual understanding of the physics concepts than the control group.

Table 3. Independent sample t test.

Groups	Mean (SD)	T	Df	Sig
Post-Experimental	29.46(5.376)	12.871	84	0.000
Post-Control	16.84(5.376)	-	-	-

This table demonstrate the t-test scores of experimental and control group, table shows that that $p<0.05$, that means that there is significant difference in the experimental and control group.

PAIRED SAMPLE T-TEST

Paired sample t-test is used when the researcher wants to find out the difference in the mean scores of the experimental group. According to Cohen and Manion (2007), paired sample t-test is less frequently used compared to independent sample t-test. Paired sample test gives the information about the change occurring in the same group before and after the intervention. It shows how much change occurred after the independent variables on the dependent variables. The posttest scores of the experimental group were analyzed on SPSS. The mean value of the scores showed that there was a highly significant difference (see Table 4). As the p value is smaller than the 0.05($P<0.05$), that probability value is highly significant and there is a difference in the mean scores of the experimental group. The conceptual understanding of the experimental group enhanced after intervention. This indicated that students learn through intervention (interactive computer simulation) and students improved their conceptual understanding level of the physics concepts.

Table 4. Paired sample t-test

Experimental group	Mean (SD)	T	Df	Sig
Pre-test	-16.780(4.252)	-25.252	40	0.000

This table demonstrate the pre and post test scores of experimental groups, table shows that that $p<0.05$, that means that there is significant difference in the scores of experimental group before and after the intervention

EFFECT SIZE

To find the magnitude of the significant difference, effect size plays a key role in quantitative research, and it has more importance than the significant statistics (American Psychological Association 1994; 2001). To check the effectiveness of the treatment and to quantify the significant difference of the two groups, effect size is used to measure the degree of significance. It tells how much the effect is that we cannot determine through statistical significance (Coe, 2004). The main advantage of the use of effect size is that it enables the researcher and readers to understand how much of the difference is due to the intervention on the experimental group, which is not possible for the statistical difference (P value) to measure (Field & Wright, 2006). There are different ways to calculate the effect size, such as r2, adjusted R2, $\eta 2$, $\omega 2$, Cramer's V, Kendall's W, Cohen's d, person's correlation coefficient r and Eta. (Cohen & Manion, 2007). Pearson's

correlation coefficient r was used to calculate the effect size in the current study; it is the one of the most common measures for calculating the effect size for a t-test (Field, 2005). The following equation was used to calculate the effect size of the paired sample t-test (Field, 2005; Cohen et al,2011). The Pearson's correlation coefficient r for paired sample t-test was o.97. Value, 0.097 showed a very large effect, which indicates that the interactive computer simulation program brought a large effect on the conceptual understanding of the students in the experimental group. For the second and third research questions, qualitative data was gathered. Interviews and focus group discussions were held with the teachers and students to know their views, perception, and experience using simulations in learning physics. In the interview, two physics teachers were involved, who participated in the intervention of the study. Both interviews were conducted after the intervention. Both teachers have more than ten years of teaching experience. The following topics were focused on while conducting interviews with the teachers: physics teachers' perception about the use of interactive computer simulation in the teaching and learning process, influence of interactive computer simulation on the conceptual understanding of the physics concepts on students, usability of the interactive computer simulation in teaching physics, factors effecting the usability of simulation program, difference in the simulation software, and traditional teaching in physics teaching. Provisional themes of the interviews and focus group discussions were formed in light of constructivist theory, and open coding was done, so that all information become part the study and was analyzed through thematic analysis.

RESULTS AND DISCUSSIONS

To answer the first research question, the scores of the pre-and posttest of the experimental and control group were compared. To find the statistical difference, the independent sample t test was applied, and results showed that there was a highly significant difference in the mean scores of the experimental and control group after the intervention ($p<0.001$), where the experimental group had mean value (29.46) and control group had (16.84). Therefore, it was found that the students of the experimental group developed a higher conceptual understanding after teaching with interactive computer simulation program than the students taught with the traditional teaching method. Findings of the qualitative data also supported the findings of the quantitative study, where teachers compared the teaching of physics with interactive computer simulation to the traditional way. Teachers commented that students of the interactive simulation classroom were involved in the teaching and learning process and responded in a better way as compared to students of the traditional classroom.

The research conducted by Trowbridge & McDermott, 1980, suggested that traditional teaching methods are not enough to deal with the misconceptions of the students. For example, mostly students have misconceptions and relate the velocity and acceleration with the position of the object; students also take the same meaning of distance and displacement. Traditional teaching methods are not enough to deal with the conceptual understanding or correcting of defective physics concepts of students. The findings of the current study is also similar to the study of Alfajam (2013), who conducted a study at primary level, where he found that an interactive computer simulation program is very helpful for teaching science subjects. It presents the information in different ways that not only involve the students but also promote conceptual understanding of the students instead of cramming. The study also concluded that an interactive computer simulation program promotes constructivist learning and enables the students to solve their own problems and the teacher only acts as a facilitator for the students (Alfajjam,2013). The researcher conducted the interviews to get in-depth views about the use of simulation program in the teaching and learning process from the teachers who were involved in the intervention and participated in the activities. Views of both teachers supported the positive effect of the interactive computer simulation program on conceptual understanding of the students and its use in teaching and learning process. Teachers held positive views about the use of interactive computer simulation program and appreciated the involvement of students in the learning process. Students were fully involved in the simulation program and participated in the activities with interest and motivation.

Teachers shared that it was a new experience for them. They talked about the different things they observed during simulation class, e.g., students who used simulation measured the mass of an object more accurately and were involved in the lesson carefully. Also, the students showed a positive attitude toward learning with simulation. Teachers discussed that for teaching physics and all other science subjects, they always use the lecture method, except one teacher who used videos for demonstrating the types of motion in the classroom. They further stated that due to high strength of students and limited time period, they

never tried any other teaching tool for the students. They further added that, due to the amount of content material (syllabus), they do not have time for lab or other activities. Thus, they never tried ICT in their teaching practices. One teacher was of the view that in simulation class the students were involved in the discussion and brainstorming process in a way that is not possible with the teacher-centered approach, where the teacher limits the students. He further added that teachers should use simulation while teaching physics and other science subjects for conceptual understanding of students.

A couple of researches concluded that using simulations helped the students to develop higher order thinking and develop brain storming capabilities Evagorou, Korfiatis, Nicolaou & Constantinou, 2009; Lieberman, Bates & So, 2009; Verenikina, Herrington, Peterson & Mantei, 2010). The use of ICT in teaching will also exclude the culture of rote memorization gradually. The views of the teachers were akin to the researcher's when he said that the simulation program enables the students to experience a real situation in classroom and encourages the students to understand the complex and dynamic relationship of physics concepts (Stevens, 1995). Students were excited in the simulation classroom. The first class showed the students how to run the simulation program, and a discussion was held to know the students' conceptual knowledge about the specific physics concepts. Then simulations were introduced and activities were done in groups. Proper time was given to the students to work on the simulation. All the discussions held with the students concluded that students were fully involved in the activities and motivated towards the group task because of the methodology adopted. Students scored high in learning physics concepts with Interactive Computer Simulation program because of the teaching methodology used, a number studies supported this idea that students learn best when they experience the things using simulations (e.g., Bullock, Moyer-Packerman, Shumway, MacDonald & Watts, 2015; Rosen & Hoffman, 2009; Steen, Brooks & Lyon, 2006).

When the students were asked about the appropriate method for teaching physics concepts, all the students stated that some of the complex physics concepts are not understand by the lecture method easily. Teachers mostly used one teaching method for teaching all the subjects, which caused the students to get bored. Students further stated that in the lecture method the teachers explain all the content material in the class and do not involve the students in discussion to maintain the discipline. Students were asked to discuss the use of ICT in the teaching and learning process; all the students concluded that teachers do not use ICT in teaching, teachers took the students' science lab once in a week, where physical instruments are limited. Due to large number of students all the students are not able to participate. Previous study also proved that technological advance tool can replace the physical equipment and are available to introduce the complex science concepts in new ways such as simulations (Fallon, 2019). In the teaching process, the main purpose of the teachers is to facilitate the students towards the conceptual understanding of the concepts. The teacher is the main asset of every learning institute.

In Pakistani culture, there is more focus on the grades and positions, so parents, teachers, and students focus on the memorization of content material for the exams, which the culture of rote memorization is promoting. Students emphasized that teachers mostly focus on the memorization of all the concepts and less on the conceptual understanding of the concepts. Study conducted by Lazonder & Ehrenhard, 2014 suggested that learning fundamental concepts of science knowledge can be assist by simulations that helped the students to focus on concepts for example evaporation, condensation and falling of the physical objects (Wang & Tseng, 2018); and heat and temperature (Zacarias, Loizou & Papaevripidou, 2012). Regarding the conceptual understanding of the physics concepts, students discussed that due to the simulation program many misconceptions of the physics concepts were cleared up; mostly students do not differentiate the concepts of vector and scalar quantities.

Students further explained that they mostly memorize the definitions and formulas of physics concepts, and because of this they are not able to relate the concepts in real life to solve complex issues. The simulation program helped the students to understand the complex concepts. The difference between pre- and posttest scores of students in the experimental group identifies the effects of interactive computer simulation program on the conceptual understanding of the students. Therefore, paired sample t-test was applied to compare the mean scores within the group. After analyzing the data, it was found that there was a highly significant difference ($p<0.001$) in the mean scored of pre (12.68) and post-tests (29.46) of the experimental group. Therefore, after analyzing the first research question, it is concluded that an interactive computer simulation program has a positive effect on the conceptual understanding of the students. The findings of the present study also supported by the study of Wang & Tseng 2018, who conducted a quasi-experimental study in Taiwanese school. His idea supported the effectiveness of the simulations for developing students' conceptual knowledge.

ANCOVA analysis indicated the significant gain of the scientific knowledge as compared to the students who had laboratory experience. Study concluded that simulations helped the students to build abstract concept more visible. Students' views were backed by the teachers' views. Teachers' views were also taken among those who experienced the simulation class and activities performed by students. Teachers held the view that students really enjoyed the learning physics concepts with the simulation program. Teachers shared many positive aspects of the simulation program and appreciated its use in physics learning. Teachers also endorsed the teacher role in simulation activities and discussions held in the student-centered approach. They further appreciated the concept formation of students instead of merely transmitting knowledge. Teachers also admitted the effective, interactive, and thought-provoking environment of the interactive computer simulation program. Teachers views are also consistent with the other studies (e.g., Jaakkola & Nurmi, 2008; Zacharias, Olympiou & Papaevripidou, 2008) endorsing the benefits of simulation in learning science subjects. Technology has made teaching process easy for educators to use artificial setting in real classroom that not only help students to develop science knowledge but also help to manipulate physical objects. Along with this little research has been found on the use of simulations for learning mathematics (e.g., Larkin, 2016; Moyer-Packenham, Shumway, Bullock & Tucker, 2015; Shin et al., 2017). The findings of the focus group discussion are also backed by the quantitative data of the current study where the hypothesis also supported the analysis of the results of pre-and posttest scores of the experimental and control group. That showed that interactive computer simulations make a significant difference in the conceptual understanding of the students. Findings of this research are also akin to the previous research, as Apkan (1989) stated that an interactive computer simulation program is very helpful for the teaching and learning process.

Interactive computer simulations provide the interactive environment for the students, which help the students to be actively involved in the learning of new concepts and also helps the students to generate new ideas. It also helps students to grow mentally by correcting their misconceptions about natural phenomena by their experiences in the simulation classroom. Conclusion This study concluded that simulations effectively supported the students' conceptual knowledge related to mass, velocity and motion. Students are also provided with the environment that can help to think critically about scientific phenomenon. students are encouraged to generalize the concept into real life. According to the Vygotsky (1978) to study scientific concepts, it's important to uncover the relation between complex scientific concepts and teaching instruction.

Students are challenged by new scientific concept learning demands and are stimulated to reprocess the learning in their own unstructured manner; here teacher needs revolutionary teaching method to help the students to processing and providing more stimuli to further cognitive development (Shayer, 2003). Lecture method is not enough to develop scientific concept at younger age. According to Vygotsky the successful teaching method is that which walks in advance of development and leads it. Teacher should know the mental capability of the students and how far ahead of development, if the concept is too far ahead of the children, then instruction needs to change (Shayer, 2003). Interactive computer simulation is a tool to demonstrate the problematic tasks for students. It is the teacher who is responsible for the appropriate use of interactive computer simulation in learning setting. The most appropriate way to use the simulation in teaching is that teacher should practice the simulation before using it in classroom. Every simulation has guideline booklet for teachers to implement it in classroom according to grade level. Every simulation is described with proper instruction of its application in classroom setting (Holec, Pfefferova and Raganova, 2004).

The interactive computer simulation program is a new concept in Pakistan, but these simulations have been used in the teaching process for almost four decades. Further research has been conducted to revise this software from time to time. The current simulations were taken from the PhET simulations project of the University of Colorado in 2006, but it gained popularity in a very short time. Keeping its effectiveness in mind, simulations are selected according to the grade level and syllabus of the F.G school. Its implication, contribution in the field, and future research

Opportunities provided the need of the incorporation of ICT in teaching and learning process.

ICT is needed for today's students, who become bored with the traditional teaching method for learning complex scientific concepts. Facilities like computer labs, projectors, and simulation programs are available, but proper training and motivation are needed to implement ICT in classrooms. Without training and practice, the teachers and students cannot get the fruitful output of the interactive computer simulation program. It is anticipated that this pioneer study will give rise to further implementation and exploration of the interactive computer simulation program at all levels. This will help our education system become more

enriched in ICT (technology-based) and more focused on learning concepts as compared to rote memorization.

Computer simulation has the potential to enhance the conceptual understanding of the students .it helps the students to bring more abstract concept into daily instruction, it can also help the students to engage in inquiry to further develop their knowledge and conceptual understanding of the content to gain meaningful practice with scientific process skills, and confront their misconceptions (Bell & Smetana, 2008). Current research was conducted to check the effectiveness of the Interactive Computer Simulation Program on the conceptual understanding of the Physics concepts, while research should be conducted to study the effectiveness of Interactive Computer Simulation Program for the conceptual understanding of other subjects like Biology and Chemistry. The present study also contributed in the field of literature about the difference between the utilization of traditional (lecture) and interactive computer simulation classroom. It also contributed about the effective utilization of constructive thoughts in classroom.

DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study are included in this published article and its supplementary information files.

CONFLICTS OF INTEREST

In accordance with my ethical obligation as a researcher, I am reporting that I do not have a financial and/or business interests and I did not receive any funding from any department or organization. This work was part of my PhD. Program. No potential competing interest was reported by the authors.

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