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Effectiveness of Simulation in Teaching Geometrical Optics

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Abstract— *Simulation is an approach used in teaching to enhance students learning especially when the concept being taught is abstract and hands on activity is not possible. However, it serves its purpose only if it is effectively implemented in the real classroom situation. Using a mixed method approach, a study on the effectiveness of simulation in teaching Geometrical Optics in class IX physics was conducted in one of the schools of Bhutan. For the quantitative approach quasi-experimental design was employed involving 70 students (35 experimental, 35 control group) and two physics teachers. Five students from experimental group and two subject teachers were interviewed. The findings of the study revealed that students taught using the simulation approach performed better than those using the conventional method. The finding also revealed that the simulation approach enriched students' attentiveness and self-exploration in learning physics. Some of the recommendations from the study included the need to provide professional training on simulation to teachers, and make adequate ICT facilities available in the schools to support learning through simulation. The study also recommends future researchers to replicate this study in other subjects to find the effectiveness of the approach.*

Keywords— ***Simulation approach, academic achievement, geometrical optics, effectiveness, physics.***

I. INTRODUCTION

Physics has been one of the most challenging and hated subjects for many years because of subject issues and inadequate teaching methods (Lasry, 2009). Research conducted by Becerra et al. (2012) revealed that students' learning and interest in physics is dramatically lower compared to other sciences. It has been noted that many educators have been hesitant to train students for active teaching styles (Slowinski, 2000). According to Kulik (2003), the deficiencies of teachers' teaching methods and strategies contribute to the low performance of students.

Owing to conventional methods, effective strategies to enhance students' comprehension and learning success in physics are of concern to some physics educators (Kiboss, 2002). Researchers have pointed out that students can hardly build concrete understanding in physics due to the complexity of teaching styles (Feltovich et al., 2001). Research indicated that replacing traditional methods with innovative strategies would help improve student learning (Barnett et al., 2002).

In the Bhutanese context, Tamang et al. (2014) added that the Bhutanese students have poor ability to apply the optics concepts in real-life situations indicating an inability to transfer the knowledge to the application part. Their study recommended the use of practical application of the Optics concept using other strategies. Optic content is one of the most relevant phenomena, but students fail to hold the correct concept in the normal teaching scenarios.

Further, Bhutan Education Blueprint 2014-2024 stated that the students found it challenging to comprehend questions related to visual problems in science, which should be remedied by using Information Communication and Technology (ICT) (Ministry of Education [MoE], 2014). The new science curriculum places the importance of ICT in the phases of learning (Tshewang, 2019).

Geometrical Optics is a topic in Physics that deals with the refraction of light and total internal reflection. The concepts like diffraction, interference, and polarization are included in classes XI and XII. Most of the Geometrical Optics concepts are abstract in nature. Due to a lack of resources and facilities in the schools, teachers are not able to explain the abstract concept clearly to the students. Computerized simulation utilizing multimedia software helps in generating Geometrical Optics diagrams to address the confusing concepts to the learners.

Students transition to learn separate discipline of science subjects (Physics, Chemistry, and Biology) in class IX from the integrated science causes insufficient basic foundation, particularly in physics and chemistry in Bhutan (Wangdi &Utha, 2020; Tenzin & Lepcha, 2012). It has been found that such transition hampers students' learning and builds confusion within topics, leading to difficulty in learning physics and losing interest in the subject (Childs, 2012). For example, students especially face problem in learning Geometrical Optics in physics, although this concept is taught to Bhutanese students as early as in class IV.

Tamang et al. (2014) has pointed out that Bhutanese students fail to apply the optics concepts in actual life situations. Similar issue was experienced by one of the present study researcher while teaching in middle and higher secondary schools for more than a decade. Tural (2015) urged teachers to explore the effectiveness of simulation and role-play to teach Geometrical Optics in the lesson to fill this gap. Further, Ndihokubwayo et al. (2020) suggested a need to study visual aids to combat misconceptions and difficulty in teaching and learning geometrical optics.

Therefore, this study was conducted to explore the learning difficulties of class IX students in understanding Geometrical Optics. The study also examined the effectiveness of simulation in teaching Geometrical Optics.

II. LITERATURE REVIEW

2.1 Simulation concept

Conceptual understanding of simulation by both teachers and students are important as they are the users in the classroom. Several concepts of simulation and its benefits are given by different authors. Gabunilas (2017) explain simulation as computer applications to provide visual duplication or represent natural occurrences like projectile motion and the flow of electrons in the circuits. Additionally, Clark et al. (2009) explains simulations as computational models of real situations or natural phenomena that allow learners to experience in that parameter leading to increased attention and focus, promoting meaningful learning experiences. Following the above ideas, simulation in the context of this study is understood as use of various computational features which will help students to understand the concepts clearly.

2.2 Benefits of simulation

Honey and Hilton (2011) point out that simulations allow learners to observe and interact with representations of processes that would otherwise be imperceptible. These aspects make simulations valuable for understanding and predicting the behavior of a variety of circumstances. It also enables students to observe and analyze the processes avoiding the possibility of misunderstanding abstract concepts. A study by Zantow et al. (2005) found that students have an opportunity to express themselves creatively and actively in the learning process when simulations are used in the classroom. Additionally, it creates an environment that makes learning genuine, which results in more engagement amongst learners. Chen and Haward (2010) found that simulation facilitates students to create an intellectual model of concepts and justifies how it can be connected to real-life situations. Further, it was revealed that students taught using simulation performed better than those not exposed to it. Computer simulations provided interactive, authentic, and meaningful learning opportunities for learners because they facilitated the learning of abstract concepts, as students would have the chance to make observations and get instant feedback (Bell & Smetana, 2008). Simulations provided learners with realistic experiences to learn and manipulate knowledge to better understand the relationship between the concepts (Widiyatmoko, 2018). Literally, simulation ease the difficult concepts and reinforce the learners to appreciate the subject.

A study conducted in Saudi Arabia using simulation reported that there was statistically significant positive relationship between teaching effectiveness and student learning performance to enhance students' classroom outcomes (Alenezi, 2019). According to Edgar Dale's learning theory, the "action-learning" techniques like simulation and modeling result in 90% retention. Student learn best when they use intuitive learning styles, which are sensory-based.

According to Edgar Dale's learning theory, the students' learning experiences were likely to be influenced and strengthened when they are actively involved in the learning process. Teachers have to choose the learning approaches that build upon more real-life experiences. It reveals that "action-learning" techniques like simulation and modeling result in 90% retention. People learn best when they use perceptual learning styles, which are sensory-based. More sensory channels are possible in interacting with a resource leading to better opportunities for students to learn from it.

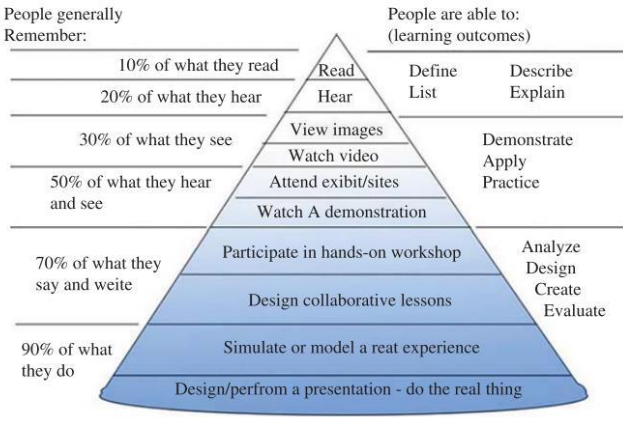

Fig. 1. Model on experiential learning for the students. From Edgar Dale's Cone of Experience by R.S. Pastore, 2013. Copyright 2013 by Eductechnolojoy

In his model (Fig 1), Dale shows that people learn best when they are actively involved in the learning process. Further, the shape of the cone and movement from top to bottom is not related to comprehension but rather the degree or levels of learning that happen when one combines and engage learning modes like reading, hearing, seeing, and doing.

III. METHODS

In this study, the concept was taught by incorporating simulated lessons as the intervention to address the conceptual learning division associated within the pragmatic worldview. The study adapted nonequivalent (pretest and posttest) control group design because there was a requirement of two groups, namely the Experimental Group (EG) and the Control Group (CG), in this research. The pretest and posttest were conducted for both groups, and intervention was carried out only for EG. For CG, the strategy followed was the normal strategy which was the conventional approach to teaching.

The convergent parallel mixed method was employed to confirm and verify achievement test with interview data. As part of qualitative data, semi-structured interviews for five students from EG and two subject teachers. An outline of it is given in the following figure 3.1

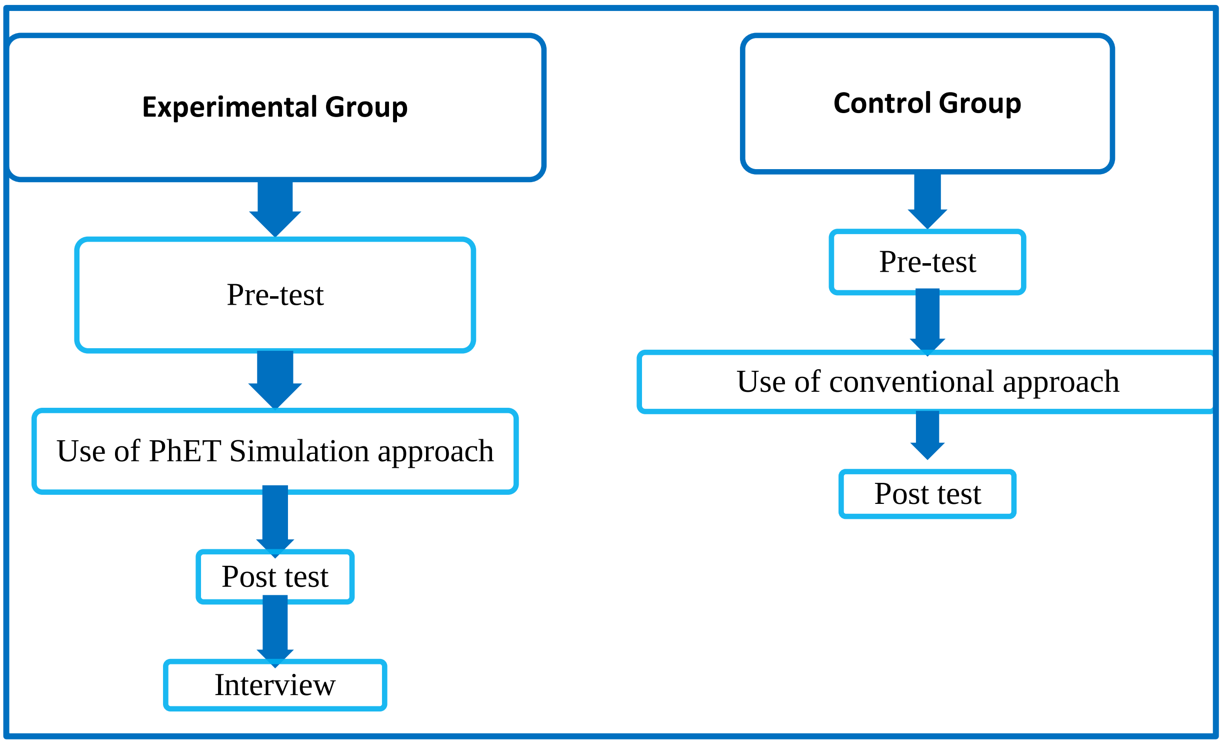

Fig 3.1 Procedures for the data collection

The pretest was used to determine students' achievement levels in both the experimental and control groups. This test consisted of 15 multiple-choice questions with a maximum score of one each for each question. The questions were set from the topic "Refraction and total internal reflection of light". Further, the test was administered to both groups. Also, both groups of students took the same achievement test for the posttest. The

Refraction and Dispersion of light units were implemented to the EG for 270 minutes (6 periods) for 14 days and conventional teacher-centered instructions were implemented for the CG. For the EG, the lesson was taught using Physics Education Technology(PhET) simulation and students used computers individually to learn the concepts in the computer laboratory.

The semi-structured interview was used based on the following advantages: Prepared to be flexible in terms of the order in which the topics were considered, and, perhaps more significantly, let the interviewee develop ideas and speak more extensively on the issues.

The questionnaires were pilot tested to 28 students of class X in a central school in eastern Bhutan. The item with Index of Item-Objective Congruence 0.75 matches its stated objectives. The average IOC for the conceptual test was 0.89, which indicated that items were reliable for the study. The interview questions were reviewed by experts to ensure the credibility of the tools

The data collected were analyzed using Statistical Packages for the Social Sciences (SPSS 22.0) to examine descriptive statistics and inferential statistics. The comparison between pretest and the post-test scores of the two groups was done by conducting pair sample t-test and independent sample t-test. Data from the interview was analyzed and interpreted following a thematic approach of Braun and Clarke (2006).

IV. RESULTS

4.1 Finding from the pretest and posttest of the control group

Table 1: Paired Sample test

	Mean	N	Std. Deviation	t	p	Remarks
Pretest EG Marks	5.31	35	1.88	14.82	0.000	With a significant difference
Post EG Marks	11.61	35	1.27			

A paired-sample t-test revealed a statistically significant difference between the mean score of pretest (M=5.31, SD=1.88) and posttest (M=11.61, SD=1.27) at t (35) = 14.82, p=0.001, α=.05 (see Table 1). Since the p-value was found to be less than the alpha level (α=0.05), it indicated that the students' understandings were enhanced because of the use of simulation approach.

Table 2: Independent t-test for pretest

Significant level: >0.05—no significant,

Student Code		N	Mean	Mean differences	Std. Deviation	t	P	Cohen's d
Pretest	Experimental	35	5.31	0.29	1.88	0.687	0.495	0.16
	Control	35	5.60		1.95			
Posttest	Experimental	35	11.61	2.21	1.27	4.24	0.000	1.22
	Control	35	9.40		1.57			

Cohen's d value: d=0.2-small effect, d=0.5-medium effect, d=0.8-large effect

From the t-test for Equality of Means, the t-test was significant as the p-value is less than the significant level (0.05) i.e., t (68) = 4.241, p< 0.001. This means that there was a statistically significant difference in achievements between the two groups in the posttest.

The Cohen's d value of pretest and posttest of CG was 0.16, which indicated that there was a small effect in students' GOAT scores within the group. The Cohen's d value of pretest and posttest of EG was 1.22, indicating that there was a large effect in students' GOAT scores within the group.

The interview analysis validated the students' views and attitudes toward simulation. Most of the students (SD1, SD2, and SD3) expressed that learning physics using simulation fosters their interaction with the simulation apps. For example, SD1 stated, "Learning physics with teaching approach like simulation made us interact, review and recall the lessons". This view was echoed by a teacher (T1) who said that the simulation lesson kept the learner engaged and interactive. Further, SD2, SD3, and SD4 shared that the simulation approach helped them to gain their attention at the beginning of the lesson, kept them focused throughout the lesson, and helped them to assess themselves at the end of the lesson. For instance, SD3 said that experiments like determining an angle of incidence and angle of refraction to find out the value of the refractive index for the various medium can be done using the PhET simulation substituting the need to carry out the laboratory setup. The same student also said the use of PhET simulation kept them alert throughout the lesson. Therefore, the interview data of students and teachers confirmed that this approach helped to keep the learners active throughout the session.

The students were also of the view that use of simulation in the lesson help learners to explore themselves and learn independently. The interview data claimed that exposing to such platform offers them to interact with simulating tools and promotes freedom to learn (S2 and S3). Similar points emerged from the teacher's data. They (T1 and T2) pointed out that such avenues allows students to relate the abstract nature of the concept using diagrams, which helps to bridge the idea relating to the real world. For instance, T1 said;

> I think simulation is a very effective teaching tool that can enhance effective learning and teaching because it helps teachers to share the concept in a simple manner and students learn easily through pictures and diagrams. Further, it improves the learner's imagination level by employing simulators in the lesson.

This approach improved the retentivity of the students as it involved maximum senses, which falls in the circle of the active learning method. Participant SD2 clearly stated that "…further it helps me to remember for a longer duration" (SD2). This was supported by T2 asserting that it helps students to retain their knowledge for a longer duration. Further, all the students participants admitted that the use of simulation in the lesson help learners to explore themselves and learn independently. Similar points emerged from the teacher participants (T1 and T2), that students get the opportunity to relate the abstract nature of the concept using diagrams that helps to simulate the idea relating to the real world.

V. DISCUSSION

The study revealed that students who were taught geometrical optics using the simulation approach performed better than the students taught with the conventional lecture method. This was because of various reasons discussed in the subsequent paragraphs.

The simulation approach helped teachers to maintain the learners' attention throughout the lesson and foster their enthusiasm for the subject. This supports the findings of Zantow et al. (2005) that the use of simulation provides students with an excellent opportunity to use creativity and actively engage in the learning process. This is because simulation can prolong the learners' activeness in the class to enhance their interest and motivation in learning physics. Similarly, the study by Guo (2020) also found that students actively participated in the simulation lesson.

The study revealed that the use of the simulation approach simplified the abstract contents and supplement the understanding of the concept to the students. This finding corroborates with the literature (Agyei et al., 2019; Scholz-Starke et al., 2018). The findings of these studies assert that computer simulation facilitated the learning of abstract concepts. This is because simulation allowed the students to make observations, receive immediate feedback, provide interactive, authentic, and meaningful learning experiences for the learners.

The study disclosed that there was a significant difference in the posttest scores of participants in Experimental Group (EG) and Control Group (CG). The finding is consistent with the study carried out by Chen and Howard (2010), who pointed out that there was a strong connection between the simulation approach and students' academic achievements.

It further reported that simulation facilitates students to remember the concept gained in the class for a longer duration. This is consistent with the findings of Guo (2014). Guo's finding revealed that students embark in the zone of active learning which leads to better retention while learning through simulation. This also complements Dale's cone of experience theory on 'experiential learning' or 'action learning'. The model claimed that students retain more when they do instead of hearing and observing the phenomena (Atesok et al., 2016). It was also evident that through the simulation approach students get the opportunity to learn the concept visually, which helps students to remember and understand the content better, leading to better achievement of higher academic scores in the test.

In addition, the study indicated that the simulation approach gave self-exploration opportunities for the learners. This has appeared from qualitative data that the majority of participants viewed that they got the freedom to learn by themselves. The aforementioned findings confirm the views shared by the teachers of Saudi Arabia that the use of simulation approach helps learners to perceive, examine, and construct scientific explanations for the phenomena their by contributing to self-exploration and enhancing freedom to learn and grow (Alenezi, 2019).

VI. CONCLUSION

The study showed that use of simulation as teaching approach in physics excites them to learn difficult concepts in physics. The results of the study from the achievement test showed that the simulation approach was an effective way of enhancing students' conceptual understanding compared to conventional textbook-oriented talk and chalk teaching. It is concluded that geometrical optics could be taught by focusing more on understanding the underlying concepts rather than rote learning. The mean difference in posttest between the two groups EG and CG were significant (MD= 6.30 and 3.80 respectively), which was due to the use of the simulation approach. Such result implies that, the impact of the intervention was significant (p= 0.001), and Cohen's d value of 1.22 indicated that the impact level of intervention was large.

VII. LIMITATIONS AND RECOMMENDATION

The limitation of the study is that it explored only effectiveness of simulation in teaching Geometrical Optics focusing on students' performance. Therefore, the study suggests future researchers to replicate the study in other topics to find out the effectiveness of the intervention. Additinally, the study recommends physics teachers to integrate technology in physics instruction to diversify their teaching approach and make it more interactive as the findings observed that use of simulation in teaching geometrical optics enhanced students' understanding of the concepts and encouraged self-exploration.

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