

**Effectiveness of PhET Simulations in Enhancing  
Conceptual Understanding of Science among High  
School Students in Palakkad District**

**BY  
NANDHINI P  
24PED009**

**A THESIS SUBMITTED TO  
AVINASHILINGAM INSTITUTE FOR HOME SCIENCE AND  
HIGHER EDUCATION FOR WOMEN  
COIMBATORE - 641043**

In Partial Fulfilment of the Requirements for the Degree of  
**MASTER OF EDUCATION**

**APRIL 2026**

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**UNDER THE GUIDANCE OF  
Dr. A. SURYALATHA**

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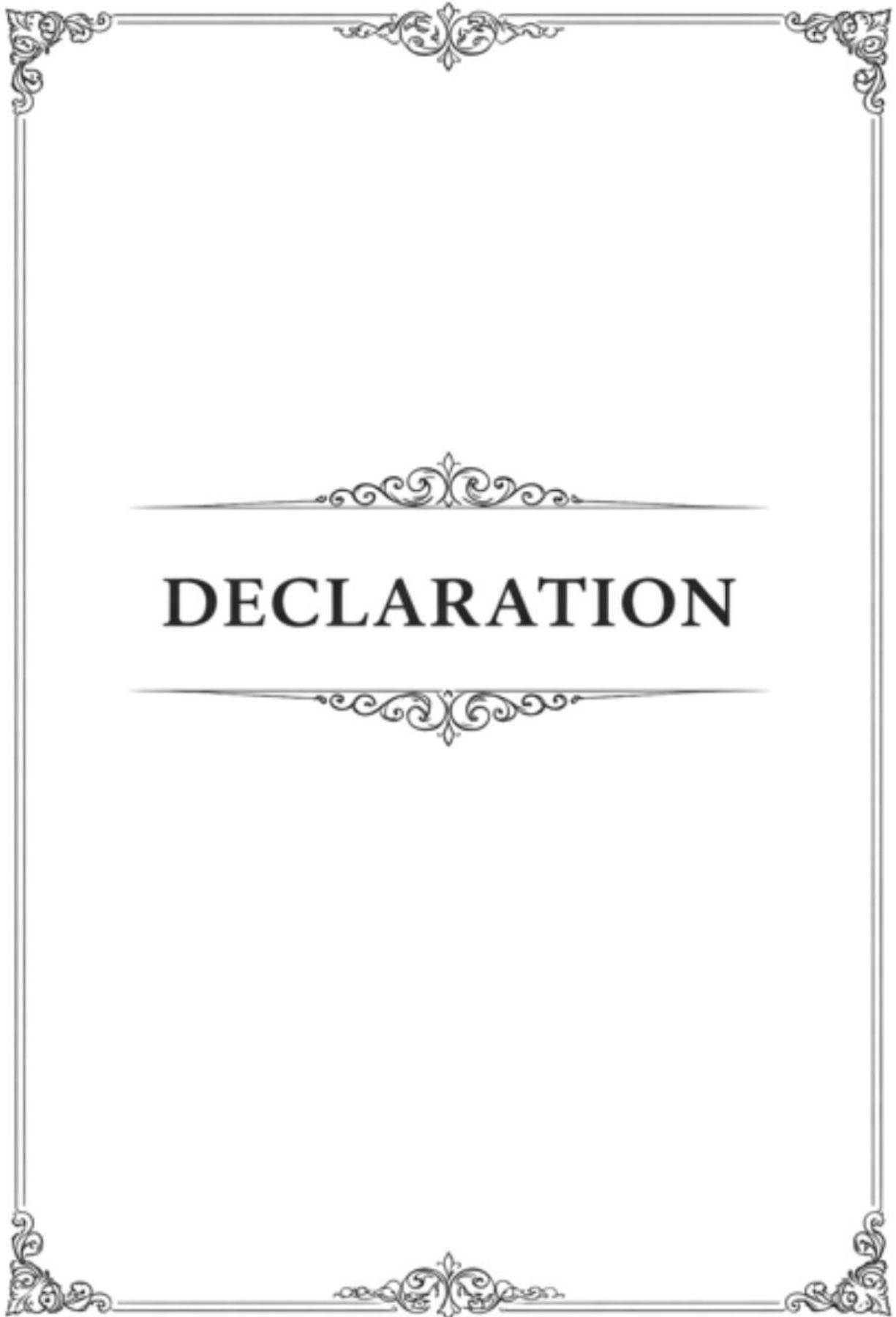
In Partial Fulfilment of the Requirements for the Degree of  
**MASTER OF EDUCATION  
APRIL 2026**

**CERTIFIED AS BONAFIDE RESEARCH WORK**

*A. Suryalatha*  
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**DECLARATION**

## DECLARATION

I, **NANDHINI P** hereby declare that the thesis entitled "**Effectiveness of PhET Simulations in Enhancing Conceptual Understanding of Science among High School Students in Palakkad District**" submitted to Avinashilingam Institute for Home Science and a Higher Education for Women, Coimbatore, in partial fulfilment of the requirements for the award of the Degree of **Master of Education**, is a record of original and independent research work done by me during the period under the supervision and guidance of **Dr.A.SURYALATHA, Assistant Professor, Department of Education** , Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, and it has not formed the basis for the award of any Degree/ Diploma/ Associateship/ Fellowship or other similar title to any candidate of this or any other University.

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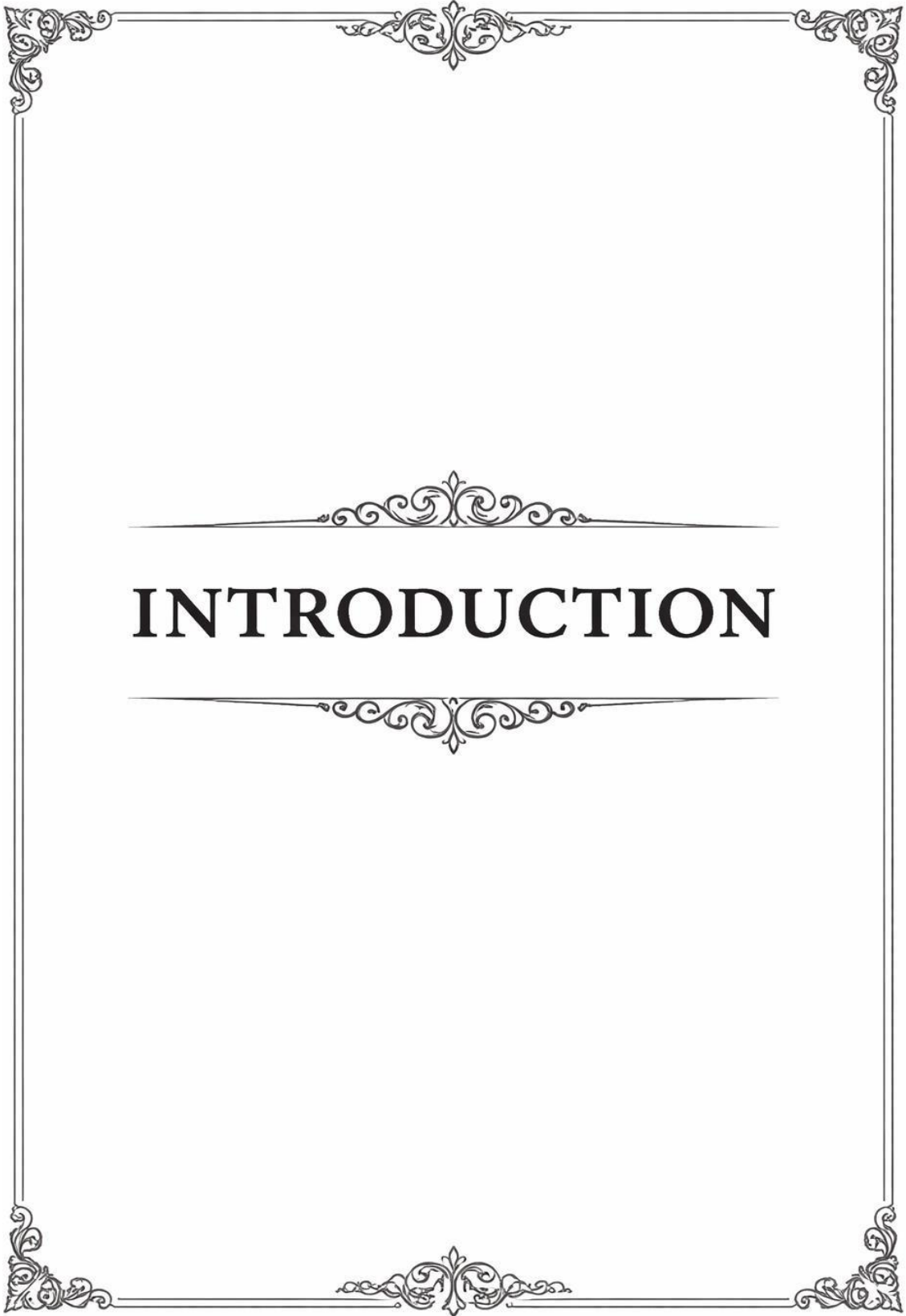
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—  
**INTRODUCTION**  
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# CHAPTER 1

## INTRODUCTION

**“Learning is most effective when students actively construct their own understanding.”**

*- Jerome Bruner*

Education plays a vital role in developing learners intellectual abilities, scientific reasoning, and problem-solving skills (Bruner, 1961; Piaget, 1970). In science education, particularly in Physics, the goal is not merely the acquisition of factual knowledge but the development of deep conceptual understanding (Mayer, 2001). However, many scientific concepts especially those related to Force and Motion are abstract in nature and difficult for students to comprehend through conventional lecture-based instruction. As a result, students often resort to rote memorization rather than meaningful learning, leading to misconceptions, low motivation, and superficial understanding (Hake, 1998; National Research Council, 2012).

Traditional teacher-centered approaches limit student interaction, visualization, and active engagement in the learning process (Bruner, 1961). Physics concepts such as force, acceleration, friction, and motion require dynamic visualization and experimentation, which are often difficult to achieve effectively through chalk-and-talk methods alone (Mayer, 2001). Consequently, there is a growing need for innovative instructional strategies that promote experiential, inquiry-based, and student-centered learning (National Research Council, 2012).

In recent years, technology-enhanced instructional tools have gained prominence in science education. One such powerful digital tool is **PhET Interactive Simulations**, developed by the University of Colorado Boulder. PhET simulations are research-based, interactive virtual environments designed to promote active exploration of scientific concepts (Perkins et al., 2006; Wieman, Adams & Perkins, 2008). These simulations allow students to manipulate variables, observe cause-and-effect relationships, and conduct virtual experiments in a safe and controlled digital setting. By enabling learners to test hypotheses and instantly visualize outcomes, PhET promotes inquiry learning and conceptual clarity.

Research studies across different contexts have reported that simulation-based instruction enhances conceptual understanding, academic achievement, and student engagement (Adams et al., 2008; Perkins et al., 2006).

Students exposed to PhET simulations demonstrate better retention, reduced misconceptions, and improved motivation when compared to those taught through traditional methods (Wieman et al., 2008). When supported by appropriate instructional guidance, these simulations facilitate meaningful learning by transforming passive learners into active participants.

In this context, the present study examines the effectiveness of PhET simulation-based instruction in enhancing the conceptual understanding of Force and Motion among high school students in Palakkad District. By comparing simulation-based teaching with traditional instruction, the study seeks to determine differences in conceptual understanding, academic performance, and retention of learning.

### **1.1 Background of the Study**

Modern educational reforms emphasize the transition from teacher-centered instruction to learner-centered pedagogies. Constructivist perspectives assert that knowledge is actively constructed through interaction, exploration, and reflection. Simulation-based learning aligns strongly with this view, as it enables learners to experiment, observe patterns, and derive meaning independently.

Physics concepts are often abstract and mathematically intensive. For instance, while studying force and motion, students must understand the relationship between mass, acceleration, friction, and applied force. Through PhET simulations, learners can manipulate these variables and immediately observe changes in motion. Such dynamic visualization bridges the gap between theoretical explanations and experiential understanding. Furthermore, interactive simulations reduce cognitive overload by presenting information through visual and interactive formats. Research by Adams et al. (2010) and Perkins et al. (2012) supports the idea that PhET simulations enhance engagement and conceptual learning by catering to multiple learning styles. Empirical findings from various studies indicate significant improvements in students' academic performance and intrinsic motivation when simulations are integrated into classroom instruction.

Despite substantial international research supporting simulation-based instruction, limited studies have explored its effectiveness within the specific educational context of Palakkad District. Regional factors such as infrastructure, technological access, teacher preparedness, and learner characteristics may influence the effectiveness of digital tools. Therefore, it is essential to investigate whether PhET simulations can significantly enhance conceptual understanding among high school students in this context.

## 1.2 Conceptual Framework

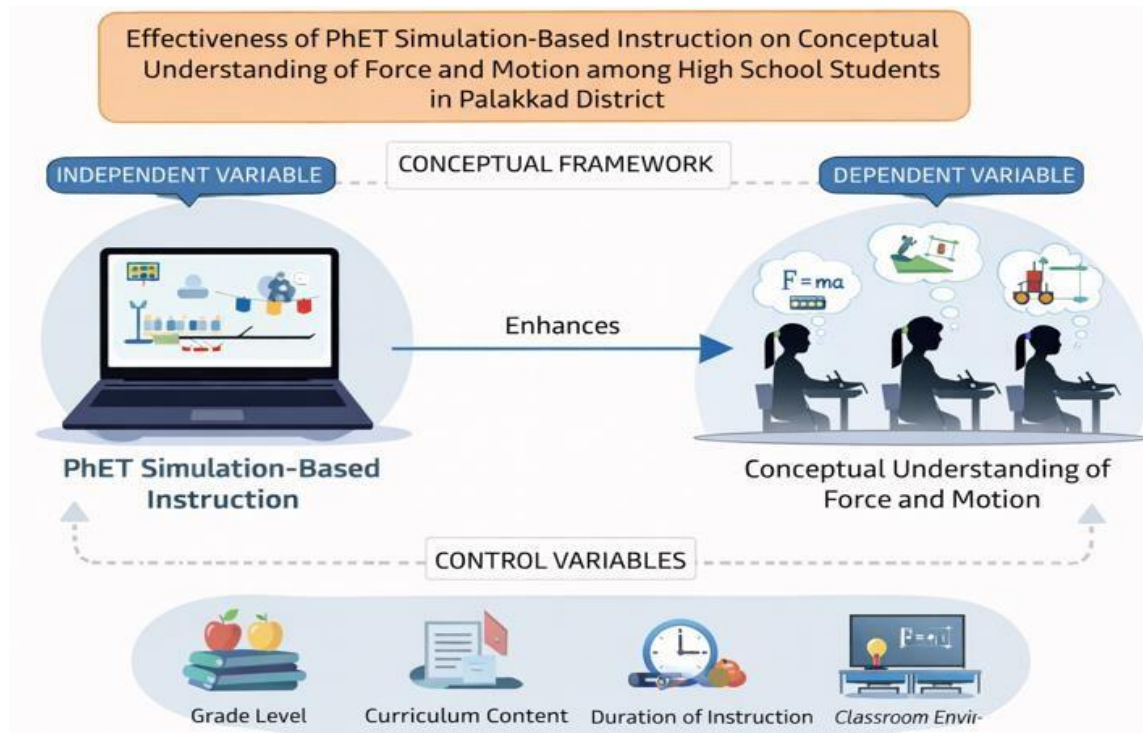
A conceptual framework provides a logical structure for the study by identifying the key variables and explaining the relationship among them. It serves as a guide for the researcher in understanding how the independent variable influences the dependent variable within the context of the investigation. The present study titled **“Effectiveness of PhET Simulation-Based Instruction on Conceptual Understanding of Force and Motion among High School Students in Palakkad District”** is designed to examine the influence of simulation-based instructional strategy on students’ conceptual understanding in physics.

In traditional classrooms, the teaching of physics concepts like force and motion is often lecture-based, which limits visualization and may lead to rote learning and misconceptions. Therefore, innovative strategies are needed to promote deeper understanding and active engagement. PhET Interactive Simulations, developed by the University of Colorado Boulder, provide interactive, experiment-based learning environments where students can manipulate variables and observe real-time changes. In this study, PhET simulation-based instruction is treated as the independent variable, while students’ conceptual understanding of force and motion is the dependent variable, measured through an achievement test.

The framework assumes that simulation-based instruction enhances learning by promoting visualization, inquiry, and active engagement, thereby reducing misconceptions and improving understanding. Control variables such as grade level, curriculum, duration, and classroom environment are maintained constant to ensure that the observed effects are due to the instructional strategy. Overall, the framework proposes that PhET simulations significantly improve students’ conceptual understanding of force and motion.

**Figure 1**

***Conceptual Framework of the study***



**1.3 Theoretical Background of the Study**

The present study is grounded in several educational and psychological theories that explain how learners acquire knowledge, process information, and develop conceptual understanding. The use of PhET simulation-based instruction in teaching physics is supported by various learning theories that emphasize active learning, visualization, cognitive processing, and conceptual restructuring (Mayer, 2001; Sweller, 1988). The major theoretical foundations relevant to the present study include Constructivist Learning Theory, Cognitive Load Theory, Multimedia Learning Theory, Inquiry-Based Learning Theory, and Conceptual Change Theory.

**1.3.1 Constructivist Learning Theory**

Constructivist Learning Theory emphasizes that learners actively construct knowledge through interaction with their environment and prior experiences. This theory is strongly associated with the works of Jean Piaget (1970) and Lev Vygotsky (1978).

According to Piaget (1970), learning occurs through the processes of **assimilation and accommodation**, where learners integrate new information with their existing cognitive structures. Vygotsky (1978) emphasized the importance of **social interaction and scaffolding**, particularly through the concept of the Zone of Proximal Development (ZPD). PhET simulations support constructivist learning by enabling students to actively explore scientific concepts (Wieman, Adams, & Perkins, 2008).

### 1.3.2 Cognitive Load Theory

Cognitive Load Theory, proposed by John Sweller (1988), explains how the limitations of working memory influence learning. According to Sweller (1988), effective instructional design should reduce unnecessary cognitive load and facilitate schema construction.

Cognitive load is categorized into three types:

- **Intrinsic Load** – Complexity inherent in the subject matter
- **Extraneous Load** – Load imposed by ineffective instructional design
- **Germane Load** – Mental effort devoted to meaningful learning

Physics concepts such as force and motion often involve complex relationships between variables, which create high intrinsic cognitive load. PhET simulations help reduce extraneous load by presenting concepts through interactive visual representations (Mayer, 2001). By providing dynamic models and immediate feedback, simulations support schema formation and deeper conceptual understanding.

### 1.3.3 Multimedia Learning Theory

Multimedia Learning Theory was developed by Richard E. Mayer (2001). This theory proposes that learners understand information better when it is presented through both verbal and visual channels rather than through words alone.

Mayer (2001) proposed three core assumptions:

1. **Dual-channel assumption** – Humans process information through visual and auditory channels.
2. **Limited capacity assumption** – Each channel has limited processing capacity.
3. **Active processing assumption** – Learning requires active cognitive processing.

PhET simulations incorporate animations, graphics, and interactive controls that allow learners to process information through multiple channels (Perkins et al., 2006).

### **1.3.4 Inquiry-Based Learning Theory**

Inquiry-Based Learning emphasizes learning through exploration, questioning, and investigation (National Research Council, 2000). In this approach, students actively engage by formulating hypotheses, conducting experiments, and drawing conclusions based on evidence. PhET simulations provide a virtual environment where learners manipulate variables and observe real-time results (Wieman et al., 2008), fostering curiosity, critical thinking, and scientific reasoning. This approach enhances deeper conceptual understanding of physics concepts such as force and motion.

### **1.3.5 Conceptual Change Theory**

Conceptual Change Theory explains how learners replace misconceptions with scientifically accurate concepts. Posner, Strike, Hewson, and Gertzog (1982) state that conceptual change occurs when learners become dissatisfied with prior conceptions and accept new ideas that are intelligible, plausible, and fruitful. Since students often hold misconceptions about force and motion, instruction must create cognitive conflict (Posner et al., 1982). PhET simulations support this process by visually demonstrating cause-and-effect relationships. The above theories collectively justify simulation-based instruction. Constructivism emphasizes active knowledge construction (Piaget, 1970; Vygotsky, 1978), Cognitive Load Theory focuses on efficient processing (Sweller, 1988), Multimedia Learning Theory supports dual-channel learning (Mayer, 2001), Inquiry-Based Learning promotes exploration (National Research Council, 2000).

Conceptual Change Theory explains restructuring of misconceptions (Posner et al., 1982). PhET simulations integrate these principles by offering interactive, visual, and inquiry-based learning experiences (Wieman et al., 2008). Therefore, the present study examines the effectiveness of PhET simulation-based instruction in improving conceptual understanding of force and motion among high school students.

## **1.4 Need for the Study**

Many high school students struggle to understand abstract physics concepts due to lecture-dominated teaching practices. This results in rote memorization, misconceptions, and poor academic performance. Therefore, there is a pressing need for learner-centered instructional strategies that promote active engagement and meaningful understanding. PhET Interactive Simulations offer experiential and visual learning opportunities that allow students to explore scientific phenomena actively. Moreover, the **National Education Policy 2020** emphasizes experiential learning, critical thinking, and technology integration in classrooms. Evaluating the effectiveness of simulation-based instruction aligns with these national educational priorities. Hence, the present study seeks to determine whether PhET simulation-based instruction significantly enhances the conceptual understanding of Force and Motion among high school students in Palakkad District.

## **1.5 Scope of the Study**

The study focuses on high school students in selected schools of Palakkad District. It examines the effectiveness of PhET simulation-based instruction on the topic of Force and Motion. The research compares an experimental group exposed to simulation-based instruction with a control group taught through traditional methods. The scope includes assessing conceptual understanding through achievement tests, analyzing gain scores, and examining retention of learning. The findings may contribute to the integration of technology-supported pedagogy in science classrooms.

## **1.6 Statement of the Problem**

Force and Motion is a fundamental concept in high school physics, yet students often struggle to achieve clear conceptual understanding due to abstract content and traditional lecture-based teaching, leading to rote learning and misconceptions. In recent years, technology-integrated approaches like PhET simulation-based instruction have emerged as effective tools for promoting interactive, visual, and inquiry-based learning. Developed by the University of Colorado Boulder, PhET simulations enable students to visualize and explore physical phenomena through active engagement. However, their effectiveness in improving conceptual understanding of Force and Motion among high school students, particularly in Palakkad District, remains underexplored. Therefore, the

present study aims to investigate the effectiveness of PhET simulation-based instruction in this context.

## **1.7 Operational Definition of Key terms**

### **Effectiveness**

Refers to the extent to which PhET simulation-based instruction improves students' conceptual understanding of Force and Motion, determined by the difference between pre-test and post-test scores and comparison with the traditional teaching method.

### **PhET Simulation-Based Instruction**

Refers to a teaching approach in which selected PhET interactive simulations related to Force and Motion are used to facilitate concept exploration, visualization, and inquiry-based learning during physics instruction.

### **Conceptual Understanding of Force and Motion**

Refers to the students' ability to comprehend, interpret, and apply concepts related to Force and Motion, as measured by scores obtained in a Conceptual understanding test developed and validated by the researcher.

### **High School Students**

Refers to students studying Physics at the high school level (Class VIII) in selected schools of Palakkad District.

## **1.8 Objectives of the Study**

The present study is designed to achieve the following objectives:

- To assess the pre-test level of conceptual understanding of Force and Motion among high school students in both the experimental and control groups.
- To determine the post-test level of conceptual understanding of Force and Motion among students taught through the traditional teaching method.
- To determine the post-test level of conceptual understanding of Force and Motion among students taught through PhET simulation-based instruction.

- To compare the mean post-test scores of conceptual understanding of Force and Motion between the experimental and control groups.
- To compare the mean gain scores of the experimental and control groups.
- To assess and compare the retention levels of conceptual understanding of Force and Motion between the two groups using delayed post-test scores.
- To estimate the practical significance of PhET simulation-based instruction on learning outcomes through effect size analysis.
- To examine the effect of PhET simulations on students' conceptual understanding of Force and Motion using regression analysis.
- To examine students feedback on PhET simulations to understand their perceived learning effectiveness.

## 1.9 Hypotheses

**H<sub>01</sub>:** There is no significant difference in the Pre-test mean scores of conceptual understanding of Force and Motion between the experimental group and the control group.

**H<sub>02</sub>:** There is no significant difference between the Pre-test and Post-test mean scores of conceptual understanding of Force and Motion among students taught through the traditional teaching method.

**H<sub>03</sub>:** There is no significant difference between the Pre-test and Post-test mean scores of conceptual understanding of Force and Motion among students taught through PhET simulation-based instruction.

**H<sub>04</sub>:** There is no significant difference in the Post-test mean scores of conceptual understanding of Force and Motion between students taught through PhET simulation-based instruction and those taught through the traditional teaching method.

**H<sub>05</sub>:** There is no significant difference in the mean gain scores of conceptual understanding of Force and Motion between the experimental group and the control group.

**H<sub>06</sub>:** There is no significant difference in the Delayed Post-test (retention) mean scores of conceptual understanding of Force and Motion between the experimental group and the control group.

**H<sub>07</sub>:** There is no significant practical effect of PhET simulation-based instruction on students' learning outcomes as measured by effect size.

**H<sub>08</sub>:** There is no significant effect on PhET simulation-based instruction on students conceptual understanding of Force and Motion.

**H<sub>09</sub>:** Students feedback on PhET simulations does not significantly indicate factors influencing engagement and perceived learning effectiveness.

### **1.10 Limitations**

- The study is limited to selected high school students in Palakkad District.
- It focuses only on the topic of Force and Motion.
- The duration of the experimental treatment is limited.
- Individual differences such as prior knowledge and digital familiarity are not fully controllable.
- Conceptual understanding is measured only through an achievement test.

### **1.11 Delimitations**

- The study includes one experimental and one control group.
- Only PhET simulations are used as the intervention tool.
- The assessment is confined to Pre-test, Post-test, and Delayed Post-test measures.

By integrating technology with conceptual learning, the study seeks to address existing gaps in traditional classroom practices. To establish a strong theoretical and empirical foundation for the investigation, a comprehensive review of related literature is presented in the following chapter.



**REVIEW OF LITERATURE**



## CHAPTER II

### REVIEW OF LITERATURE

**“Interactive simulations can make invisible scientific processes visible and help students build a deeper understanding of physics concepts.”**

A Literature review is a crucial part of education research aiding in comprehending different research aspects. It enables researchers to gain clarity on methodology data analysis and interpretation by examining similar studies. The review includes not only previous research by other scholars but also relevant theories, articles, and journals connected to the study. It encompasses an analysis of related studies, often referred to as prior research. In the present study, the researcher reviewed various national and international studies related to the use of **simulation-based learning**, particularly **PhET interactive simulations**, in teaching physics.

The review mainly focuses on studies related to the teaching of **force and motion**, the effectiveness of simulation-based instruction, and the comparison between **traditional teaching methods and technology-supported learning**. The review of related literature relevant to the present study is presented under the following headings:

#### **2.1 Studies on the Effectiveness of PhET simulations in Science and Physics learning**

**Assaf (2025)** conducted a mixed-methods study aimed at examining the effectiveness of interactive simulations, particularly PhET, in improving students comprehension of chemistry concepts at a private high school in Abudhabi. The research targeted 20 Emirati senior female students and was executed during the 2018-2019 academic year. Data collection involved a validated questionnaire comprising 12 Likert-scale statements designed to evaluate students' attitudes and conceptual understanding, in addition to three open-ended questions intended to gather detailed insights. Quantitative data were analyzed through descriptive statistics while qualitative responses underwent thematic analysis. The results indicated that the interactive simulations created by PhET significantly boosted students confidence, engagement, and overall learning experiences in chemistry. The study also demonstrated that PhET simulations were effective in both synchronous and asynchronous learning contexts.

**Tuyizere and Rutegwa (2024)** conducted a study to determine if PhET Interactive Simulations could students comprehension of protein synthesis. The research involved 107 secondary school Biology students. Of these, 57 students were instructed using PhET simulations (experimental group), while 50 students received traditional classroom instruction (control group). The researchers administered a test to both group prior to and following the instruction. Additionally, they inquired about the students attitude towards learning the subject. The findings indicated that students who utilized PhET scored significantly higher than those who were taught through conventional methods. The study concluded that PhET simulation facilitate the understanding of challenging Biology topics and contribute to a more enjoyable learning experience for students.

**Cezar et al. (2024)** conducted a study to investigate the impact of PhET simulations on the academic performance and engagement of Grade 10 Physics students in Iligan City, Philippines. The research involved 60 students who were split into two groups: an experimental group that received instruction through computer simulations created by PhET Interactive Simulations, and a control group that was taught using traditional lecture-based methods. The research indicated that students utilizing PhET Interactive Simulations achieved higher scores in Physics compared to those instructed through conventional methods, demonstrating enhanced comprehension and problem-solving abilities.

**Sains (2024)** investigated the impact to integrating PhET Interactive Simulations with Interactive Conceptual Instruction (ICI) on students comprehension of Physics concepts in Indonesia. The research involved 62 high school students comprising 32 in the experimental group and 30 in the control group. The experimental group received instruction through both PhET simulations and ICI, whereas the control group was taught using conventional methods. A pretest and posttest were administered, and the outcomes were evaluated using t-tests and N-Gain scores.

**Sakona et al. (2023)** carried out a research study entitled. The Effectiveness of Utilizing PhET in Increasing the Comprehension of Physics Concepts, Which was published in Jurnal Ilmiah Pedidikan Fisia. The objective of the study was to determine if PhET Interactive Simulations could enhance the understanding of Physics concepts

among eleventh-grade students at SMA Negeri 2 Makassar. The researchers employed a true experimental design featuring a pretest-posttest control group.

Students were randomly selected, and their comprehension was assessed through tests aligned with Bloom's Taxonomy levels, including translation, interpretation, and extrapolation. The findings revealed that students who engaged with PhET simulations exhibited greater improvement compared to those instructed through conventional methods.

**Uwambajimana et al. (2023)** carried out a quasi-experimental study to investigate the effect of PhET simulation on students' conceptual grasp of electrostatics in selected secondary schools within Muhanga District, Rwanda. Electrostatics was recognized as one of the most abstract and difficult subjects in physics, frequently resulting in inadequate student comprehension when presented through traditional teaching methods. The research involved two distinct groups: a control group that engaged in traditional teaching methods and an experimental group that utilized PhET Interactive Simulations.

**Sharma and Shukla (2023)** assessed the influence of interacting PhET simulations on the comprehension of kinetics and motion among Class XI students in physics. The research employed a mixed-methods approach, incorporating pre-post assessments alongside focus group discussions. The experimental group utilized PhET simulations to investigate concepts related to motion graphs, velocity, and acceleration, whereas the control group participated in traditional lecture demonstrations. The quantitative findings indicated that the simulation group experienced significantly higher improvements in their conceptual test scores in comparison to the control group, particularly in their ability to interpret motion graphs and relate mathematical representations to physical phenomena.

**Najib et al. (2022)** conducted a study to determine if PhET Interactive Simulation could enhance students' performance in Physics. PhET is an online resource that employs interactive and visual simulations to assist students in grasping challenging physics concepts. The researchers developed lesson plans that incorporated PhET activities. The study included 60 students - 30 students engaged with PhET simulations (experimental group) and 30 students were taught using traditional instructional methods (control group). Both groups underwent a pretest and a Post-test consisting of multiple-choice

questions to evaluate their learning. The findings indicated that students utilizing PhET experienced an improvement in their test scores, whereas those who were taught through conventional methods exhibited minimal progress. This suggests that the use of PhET simulations facilitates a better understanding of Physics among students.

**Amir and Nor (2022)** investigated the effectiveness of PhET simulations in teaching optics concepts to secondary school physics students. Employing a quasi-experimental design, the researchers assessed performance outcomes and student engagement by comparing an experimental group (which received PhET simulation-supported instruction) with a control group (which experienced traditional teaching methods). The experimental group engaged with interactive simulations that demonstrated light behavior, reflection, and refraction, enabling students to adjust parameters such as angles and media. Post-test findings revealed that the experimental group achieved significantly higher scores on conceptual assessments compared to the control group

**Patel (2022)** carried out a fascinating study on how PhET interactive simulations can be used to teach high school students about electricity. The research looked into how these simulations serve as innovative teaching tools that help students grasp physics concepts, especially topics like Ohm's law, resistance, and electric circuits. It highlighted the importance of strengthening basic science education to tackle global challenges outlined in the United Nations Agenda 2030 for Sustainable Development, which includes critical issues like energy, health, and food security. The results showed that PhET simulations significantly enhance students understanding by allowing them to visualize and engage with complex physics ideas.

**Aydin and Bozkurt (2021)** examined the impact of PhET simulations on university students comprehension of electric circuits within an introductory physics course. The research employed a quasi-experimental design featuring pre- and Post-tests to evaluate an experimental group (which integrated PhET simulations into their instruction) against a control group (which relied on traditional lectures and textbook learning). The findings indicated that the experimental group experienced significantly greater improvements in their conceptual understanding of electric circuits compared to the control group.

**Gani et.al (2020)** carried out a research study entitled “Improving Concept Understanding and Motivation of Learners through PhET Simulation,” which was published in the Journal of Physics: Conference Series. The objective of the study was to determine if PhET Interactive Simulations could enhance students comprehension of Physics concepts and their motivation to learn. The researchers employed a quasi-experimental design. From four Grade VIII classes, two were randomly chosen.

The findings indicated that students who engaged with PhET simulations exhibited greater improvement in their understanding compared to those in the traditional class.

**Ozca et.al. (2020)** carried out a research study entitled “The Effect of PhET Simulation-based Instruction on 6<sup>th</sup> Grade Students Achievement Regarding the Concept of Greenhouse Gas,” which was published in Science Education International. The objective of the study was to assess the effectiveness of PhET simulation-based instruction in enhancing students academic performance concerning the concept of the greenhouse effect. The findings indicated that students utilizing PhET simulations achieved significantly higher scores compared to their counterparts in the control group, thereby demonstrating that teaching through simulations was more effective in enhancing students understanding of the greenhouse effect.

**Antonio et al. (2018)** carried out a quasi-experimental study aimed at assessing the impart of PhET interactive simulation-based activities on the academic performance of Grade seven students in science. The experimental group received instruction through PhET - simulations, where as the control group adhered to the conventional teaching approach Pre-test results indicated no signification differences between the two groups confirming their comparability. Following a ten-week intervention, both group, exhibited improvement; however, the experimental group showed a notably greater increase in post test scores. The results suggested that PhET simulations effectively improved student academic performance and fostered their motivation, engagement, and active participation in science learning.

**Batuyong and Antonio (2018)** carried out a study focusing on the effectiveness of PhET Interactive Simulations in the teaching of Electromagnetism. The researchers

employed a Research and Development (R&D) methodology to create PhET simulation-based activities, which were meticulously validated by subject matter experts to guarantee quality and precision. The study included 200 Grade 10 students and utilized a one-group pre test-post test design to assess improvement in academic performance. The results indicated a notable increase in students test scores following the implementation of the simulation-based activities. Additionally, students provided positive feedback, expressing that learning Physics became more engaging, enjoyable, easier to comprehend, and more relatable to real-life scenarios.

## **2.2 Studies on PhET Simulations and Students' Engagement and Motivation**

**Finelstein and colleagues (2021)** carried out a mixed-methods investigation to examine the effects of PhET simulations on students' conceptual understanding and cognitive engagement in introductory physics. The experimental group engaged with PhET simulations during guided inquiry activities, whereas the control group adhered to traditional lectures and problem-solving exercises. From a quantitative perspective, students in the simulation group attained significantly higher scores on conceptual inventories and problem-solving evaluations compared to the control group. Qualitative insights indicated that the simulations promoted enhanced cognitive engagement: students were more inclined to formulate predictions, test hypotheses, correct misconceptions, and participate in peer discussions.

**Rahayn and Nisa (2018)** conducted a study to determine if PhET simulations could enhance students performance and address misconceptions in the subjects of electricity and magnetism. This quasi-experimental research included an experimental group that utilized PhET simulations and a control group that engaged in traditional learning methods. Both group underwent pre and post-conceptual assessments. The findings indicated that the experimental group attained significantly higher scores on the Post-test, suggesting improved conceptual comprehension and a reduction in misconceptions. A considerable number of students expressed that PhET simulations facilitated the visualization of abstract concepts and that interacting with these models bolstered their confidence in tackling physics problems.

**Trumper (2017)** investigated the impact of PhET interactive simulations on students conceptual comprehension and interest in physics subjects related to force and motion. Through the use of pre- and Post-test evaluations with high school students, the research revealed that instruction supported by PhET significantly enhanced conceptual learning in comparison to traditional lectures. The findings indicated that engagement with PhET simulations led to an increase in positive attitudes, curiosity, and a greater willingness to pursue self-directed exploration. Students noted that the simulations rendered abstract physics concepts more comprehensible and enjoyable. The study concluded that interactive simulations not only improve understanding but also foster greater enthusiasm and confidence in science education.

**Jose and Perez (2016)** conducted a fascinating study to explore how effective PhET interactive simulations are in teaching energy concepts within physics. The main goal was to see how this simulation based learning approach impacts students understanding and students interest in the subject. The researcher integrated PhET simulations into classroom lessons and assessed students learning through tests and their feedback. The study also highlighted that these simulations allow students to independently explore scientific ideas and learn through hands on experimentation. Moreover students noted that the visual and interactive elements of the simulation made it much easier for them to grasp those tricky abstract physics concepts.

Ultimately, the study concluded that incorporating PhET simulations into physics education significantly boosts student engagement, enhances conceptual understanding, and improves overall learning outcomes.

**Adams et al. (2015)** focused on how interactive visualizations support students in understanding abstract scientific concepts. The researchers found that simulations allowed learners to manipulate variables, observe outcomes, and build conceptual connections between theoretical principles and real-world phenomena. Students demonstrated improved engagement and deeper conceptual understanding when simulations were integrated with guided instruction. The findings suggested that interactive simulations can effectively support inquiry-based learning and help students overcome common misconceptions in physics concepts such as force, motion, and energy.

**Bandoy et al. (2015)** conducted a study titled *The Effectiveness of Using PhET Simulations for Physics Classes*. The purpose of the study was to evaluate the usability and effectiveness of PhET simulations in teaching physics concepts in both lecture and laboratory environments. The researchers collected data from physics teachers and students using questionnaires and feedback surveys. The findings indicated that PhET simulations are easy to use and provide a visual representation of complex physics concepts, which helps students understand difficult topics more clearly. Students also reported increased interest and motivation when learning with simulations compared to traditional teaching methods. The study further highlighted that simulations support interactive learning by allowing students to manipulate variables and observe the outcomes instantly.

**Rutten et al. (2015)** conducted a study to examine the effectiveness of computer simulations in science education, particularly in physics classrooms. The researchers analyzed how simulation-based learning environments support students' conceptual understanding and inquiry skills. The findings revealed that simulations help students visualize abstract scientific phenomena that are otherwise difficult to observe in traditional classroom settings. The study also showed that students who learned with simulations demonstrated improved conceptual understanding and higher levels of engagement compared to those taught using conventional methods.

### **2.3 Studies on Simulation-Based and Inquiry-Based Learning in Physics Education**

**Torrevillas et al. (2023)** conducted a study examining the effectiveness of PhET based inquiry learning with embedded formative assessment in teaching projectile motion to non-STEM Grade 11 students. Grounded in constructive epistemology, the study emphasized active learning and knowledge construction through hands-on experiences. A 30-item teacher-made test and formative assessments were used to evaluate students understanding and monitor progress. Using a quasi-experimental design, the researchers selected 34 students each from the ABM (and HUMSS (Humanities and Social Sciences) stands. Statistical tools such as weighted mean, paired-sample t-test, ANOVA, and standard deviation were applied to analyze the data. The findings revealed that students

exposed to PhET simulations combined with inquiry-based learning significantly outperformed those taught through traditional lecture methods.

**Toma (2023)** took a closer look at the hurdles and teaching opportunities that come with using PhET (Physics Education Technology) simulations in secondary science classroom across Bangladesh. The study pointed out that while these simulations have the potential to tackle common educational challenges like the shortage of lab equipment, overcrowded classrooms, and the reliance on traditional lectures their implementation in Bangladeshi schools is still quite limited. The research included seven PhET workshops held in Dhaka, engaging 129 teachers, both in-service. Ultimately, the study emphasized that enhancing teacher training programs and upgrading technological infrastructure are crucial steps for successfully integrating PhET simulations science education in Bangladesh.

**Adimayuda et al. (2022)** investigated the efforts of PhET simulations on high school students understanding of momentum and impulse in a physics class. The quasi-experimental research involved two groups: an experimental group that engaged with PhET simulations supplemented by guided worksheets, and a control group that received traditional instruction. Pre- and Post-tests were conducted to evaluate knowledge gains, revealing that the experimental group experienced significantly greater improvements in their conceptual understanding. The experimental group indicated a heightened interest and perceived relevance of the physics material to real-world situations.

**Adimayuda et al. (2018)** carried out a study to investigate the impact of PhET Interactive Simulations on high school understanding of momentum and impulse concepts. Employing a quasi-experimental design, the researchers categorized students into an experimental group that utilized PhET simulations along with guided worksheets, and a control group that received conventional. Both groups participated in conceptual assessments based on Bloom's taxonomy before and after the intervention. The findings revealed that students engaging with PhET simulations exhibited a significantly greater enhancement in their understanding compared to those who were taught through traditional methods, suggesting that the simulations facilitated a clearer comprehension of abstract physics concepts.

**Adimayuda et al. (2016)** studied the role of PhET simulations in facilitating guided-inquiry learning within science classroom. Their research concentrated on the engagement of undergraduate and secondary students with simulations related to mechanics and energy topics. Students participated in PhET activities designed around inquiry tasks, where they were prompted to make predictions, manipulate variables, and articulate their findings. Assessment results indicated that students utilizing PhET simulations in guided learning sequences exhibited notable improvements in conceptual understanding when compared to their peers who received conventional instruction.

**Moore et al. (2016)** carried out a study to investigate the impact of PhET Interactive Simulations on high school students understanding of momentum and impulse concepts. Employing a quasi-experiment design, the researchers categorized students into an experimental group that utilized PhET simulations along with guided worksheets, and a control group that received conventional instruction.

Both groups participated in conceptual assessments based on Bloom's taxonomy before and after the intervention. The findings revealed that students engaging with PhET simulations exhibited a significantly greater enhancement in their understanding compared to those who were taught through traditional methods, suggesting that the simulations facilitated a clearer comprehension of abstract physics concepts.

**Kohnle et al. (2015)** investigated the effectiveness of interactive simulations in improving students' understanding of physics concepts. The study focused on how simulation-based learning environments encourage active participation and conceptual exploration among students. Through classroom implementation and assessment of student performance, the researchers found that students who learned through interactive simulations developed better problem-solving skills and deeper conceptual understanding compared to those taught using traditional lecture methods. The study also emphasized that simulations allow learners to experiment with different variables and observe cause-and-effect relationships in real time.

**Wee (2015)** carried out a fascinating case study to dive into how simulation tools can be used to teach motion concepts like free fall and projectile motion. The main goal of their research was to see how learning through simulation affects students

understanding and outcomes in Physics. They compared classroom activities and assessments to evaluate the performance of students who learned with simulation-based instruction against those who were taught using traditional lectures. The findings revealed that students who engaged with simulation tools not only grasped the concepts better but also performed academically.

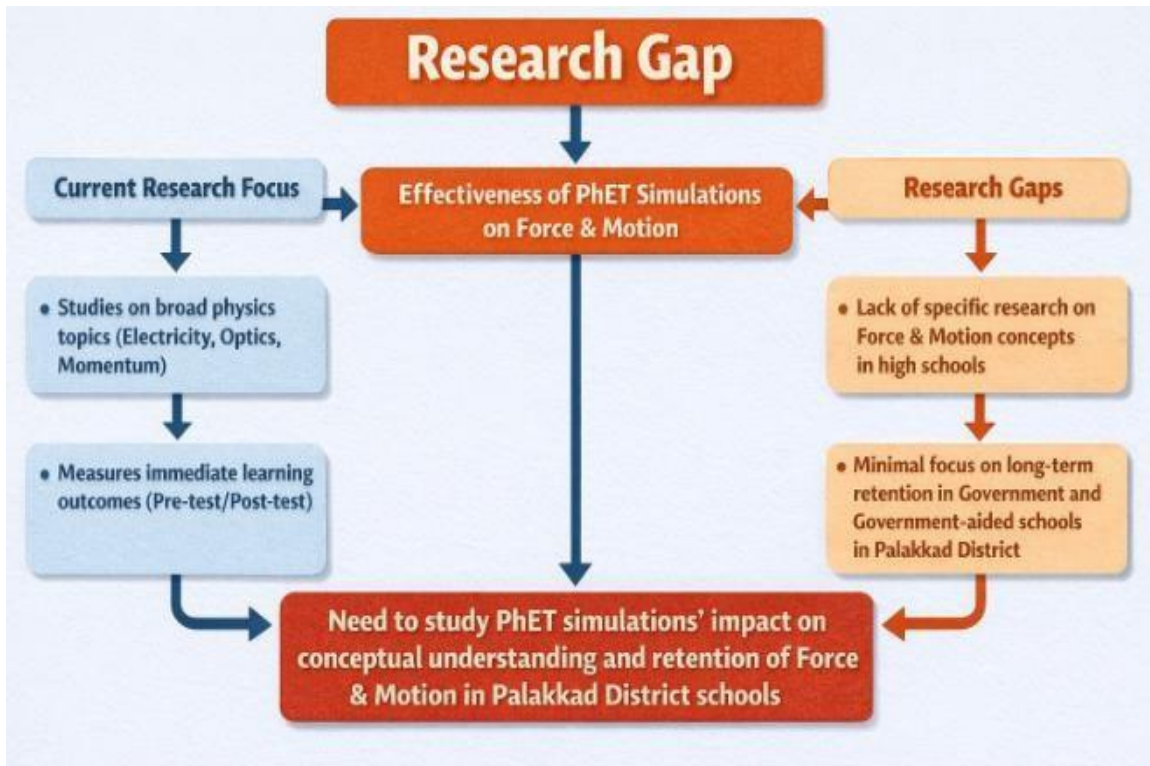
**Chamberlain et al. (2014)** conducted a study to examine how instructional guidance influences students' engagement with interactive simulations. The study aimed to investigate the effectiveness of PhET simulations in promoting conceptual understanding when combined with different levels of instructional support. Data were collected through classroom observations and student responses during simulation-based activities. The results showed that students who used simulations with appropriate guidance demonstrated higher engagement, deeper exploration of concepts, and improved conceptual understanding compared to students who used simulations without guidance. The study also reported that guided inquiry with simulations encourages students to ask questions, test ideas, and reflect on their learning process.

## **RESEARCH GAP**

A review of related literature reveals that numerous studies have established the effectiveness of PhET simulations in improving student academic achievement, engagement, and general conceptual understanding in science and physics. However, most of these studies have focused on broad physics topics such as electricity, optics, electrostatics, and momentum, with limited attention given specifically to the concepts of **Force and Motion** at the high school level. Furthermore, many previous investigations have primarily measured immediate learning outcomes using Pre-test and Post-test designs, with minimal emphasis on **long-term retention through Delayed Post-tests**. Additionally, there is a scarcity of empirical studies conducted within the context of **Government and Government-aided schools**, particularly in **Palakkad District**. Therefore, a clear research gap exists in examining the effectiveness of PhET simulation-based instruction on the **conceptual understanding and retention of Force and Motion among high school students in Palakkad District**, which the present study seeks to address.

**Figure 2**

*Research gap*



The review of related literature provides a theoretical and empirical foundation for the present study. Based on these insights, the methodology adopted for the investigation is presented in the following chapter.



**RESEARCH  
METHODOLOGY**

## CHAPTER III

### METHODOLOGY

*“Research is to see what everybody else has seen, and to think what nobody else has thought.”*

— *Albert Szent-Gyorgyi*

Research methodology refers to the systematic approach a researcher follows from identifying a problem to drawing conclusions. Its purpose is to ensure the research is conducted scientifically and validity. It includes various procedures and techniques for carrying out a study, making it essential for researchers to understand and apply appropriate methods. Research methodology encompasses both general and specific research activities, and mastering it enhances comprehension for research processes.

The present study focused on exploring how effective PhET Simulation-based instruction is in enhancing high school students to grasps the science concepts Force and Motion from class VIII using Quasi experimental design involving 60 students split into control and experimental groups. The experimental group learned through PhET simulations, while the control group experienced traditional teaching methods. To evaluate the improvement in students' understanding, we conducted an achievement test both before and after the intervention.

In this chapter, the investigator discussed the method adopted, area of study, population, sample of the population, sampling technique, and instrument for data collection, administration of the instrument and method of data analysis.

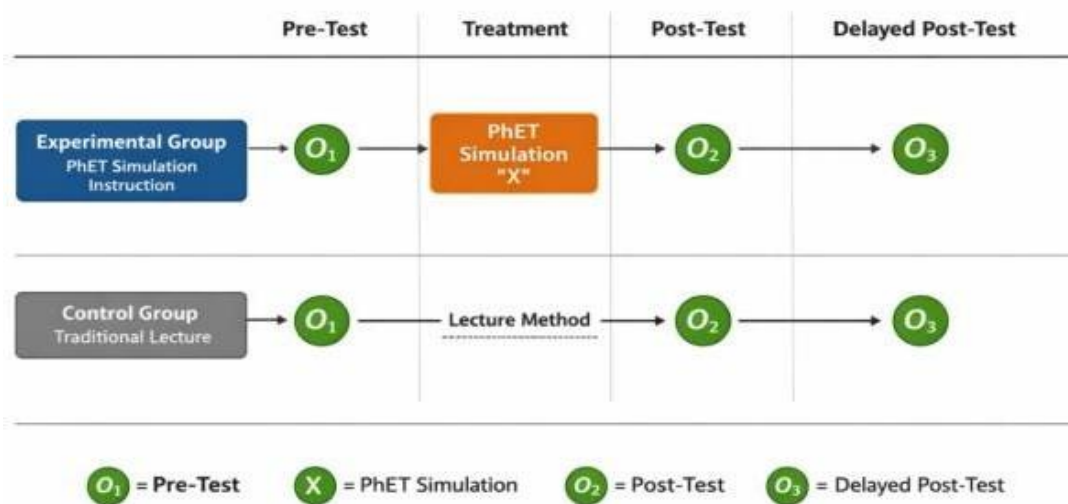
#### **3.1 Method adopted in the present study**

The present study adopted a **quasi-experimental research design**, specifically the Pre-test & Post- test for Non equivalent control group design. A true experimental design was not an option since we had to work with existing classroom groups, making random assignment of students impossible. So, we use quasi experimental approach to evaluate how effective PhET simulation based instruction could be. In this setup, we selected two groups one experimental and one control group. Both groups took a Pre-test to find their initial understanding of Force and Motion concepts. After the pre test, the

experimental group engaged in learning through PhET simulation based teaching, while the control group received instruction via the traditional method. Once the intervention completed both the groups took a post test to assess their learning outcomes. We also conducted a delayed post test after a certain period to check how well they retained what they learned. This design allowed us compare the performance of the two groups before and after the intervention, helping us determine if the simulation- based method significantly enhanced students understanding the concepts.

**Figure 3**

*Method adopted in the present study*

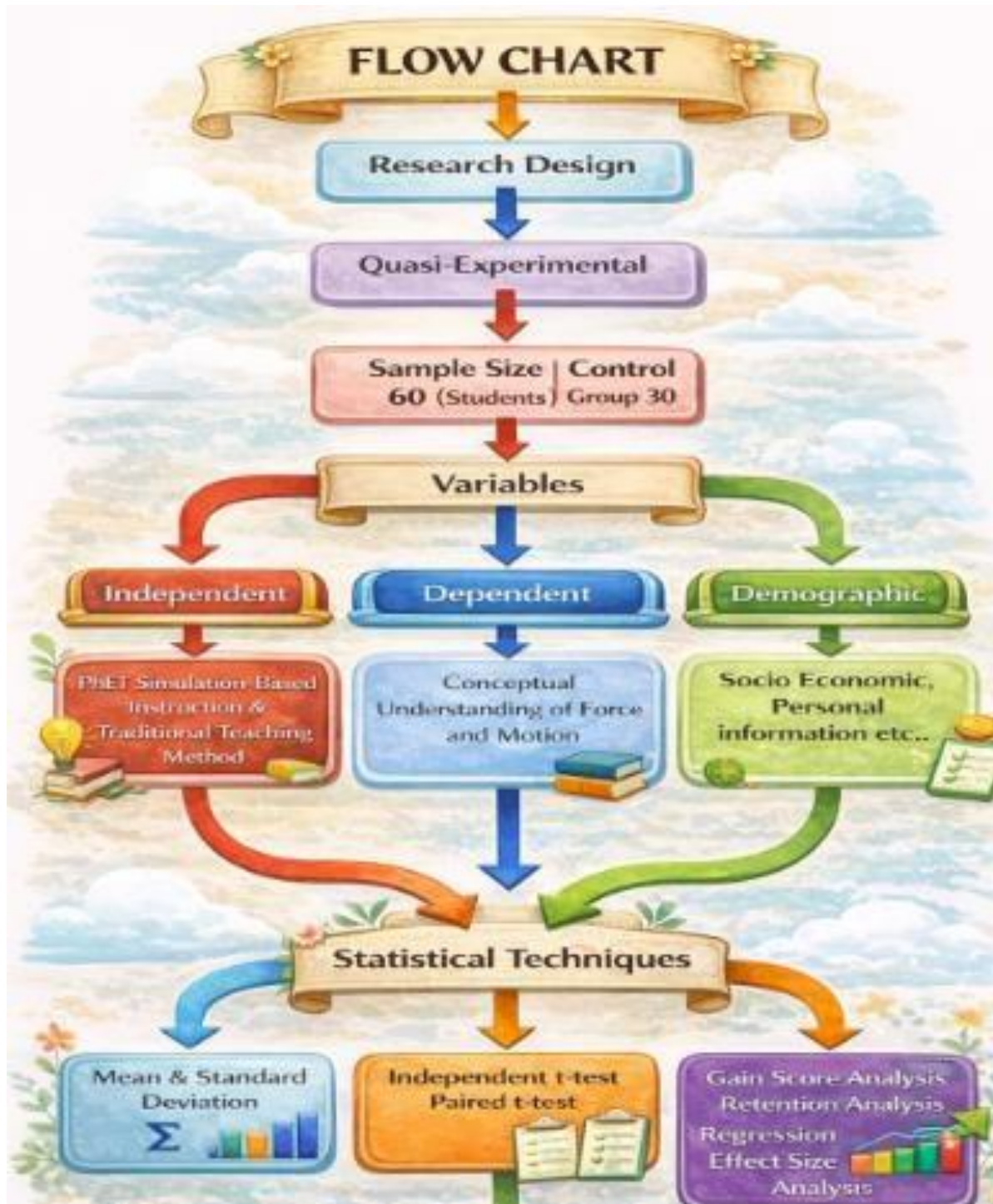


**3.2 Research Design**

Research design is the blue print for conducting research study, outlining the methods, procedures, and techniques to be employed. It encompasses decisions about data collection, sampling, and analysis, ensuring the study’s objectives are met effectively. A well designed research study enhances the validity and reliability of the findings while guiding the researcher in achieving their research goals.

Figure 4

*Research Design*



### 3.3 Area of Study

The study was conducted in **Palakkad District, Kerala**. Two schools were selected:

- Government Vocational Higher Secondary School, Agali
- Arogyamatha Higher Secondary School (Government Aided), Kottathura

These schools were selected based on accessibility and administrative permission.

### 3.4 Population of the Study

The population consisted of all high school students studying Class VIII Science in Palakkad District following the Kerala State Board syllabus.

### 3.5 Sample

**Purposive sampling** technique was used to select the sample for collecting data. It is the basis for other types of probability sampling. In this method of selection, every item has an equal chance to be selected.

The sample of the present study consisted of **60** Students of **Government School (30)** and **Government aided School (30)** in Palakkad district.

### 3.6 Variables of the Study

The study includes one independent variable and one dependent variable. The independent variable was the method of instruction, which had two levels, PhET Simulation based instruction and the traditional teaching method. The dependent variable was student conceptual understanding of Force and Motion, as measured through an achievement test developed by the researcher. The study aimed to determine whether the independent variable (method of instruction) had a significant effect on the dependent variable (conceptual understanding).

### 3.7 Tools used in the study

#### 3.7.1 Personal Data Sheet

The personal data sheet includes basic information about the sample. The basic information section primarily gathers information such as Gender, School type, parental Educational level, Socio economic Status, Exposure to PhET Simulation, Interest in

Science Branch, Previously used method in science teaching and Academic scores in Science. (APPENDIX 1)

### **3.7.2 Achievement Tests on Force and Motion**

#### **i) Pre-test & Post-test**

The investigator developed and standardized the test for both the Pre-test and Post-test to assess how well students grasped the concepts of Force and Motion. To ensure consistency and enable fair comparisons between the control and experimental groups, the same test format was utilized for both evaluations.

#### **1. Purpose of the Test**

- The Pre-test was conducted to assess the previous knowledge of students using the questionnaire and to establish equivalence between the control and experimental groups.
- The Post-test was conducted using the same questionnaire after the instructional treatment to measure the effectiveness of the intervention and to assess the improvement in student conceptual understanding.

#### **2. Specification of Content**

The unit selected for both Pre-test and Post-test was “*Force and Motion*” from Class VIII Science (**Kerala State Board syllabus**), as it provides the foundational concepts necessary for further learning in physics.

#### **3. Instructional Objectives**

The tests were designed to assess the following objectives in the cognitive domain:

- **Knowledge**
- **Understanding**
- **Application**
- **Skill**

#### 4. Preparation of Blueprint

A common blue print was prepared for both Pre-test and Post-test to ensured content validity and balanced representation of all topics. The table below represents the number of items to be included in relation to the particular objective.

**Table 1**

##### *Blueprint*

<b>Content \ Objective</b>	<b>Knowledge (O)</b>	<b>Understanding (O)</b>	<b>Application (O)</b>	<b>Skill (O)</b>	<b>Total</b>
Force & Effects	4(1)	3(1)	2(1)	1(1)	10
Types of Forces	3(1)	2(1)	1(1)	1(1)	7
Friction	2(1)	2(1)	1(1)	1(1)	6
Balanced Forces	2(1)	1(1)	1(1)	0	4
Units	2(1)	1(1)	1(1)	1(1)	5
Motion	3(1)	3(1)	2(1)	0	8
Total	16	12	8	4	<b>40</b>

#### 5. Construction of Test Items

A draft question paper was prepared consisting of 45 questions. Most of the questions were framed for the level of average students. Modifications were made on the suggestions of subject experts. The answer sheets were given to students for pilot study. The students were provided with 1 mark for each correct answer and 0 marks for each wrong answer. Draft question paper was given in (**APPENDIX 2**)

#### 6. Item Analysis

Item analysis was done by administering the test to 20 students to determine the difficulty index of each item. Items with a difficulty index around 0.9 were considered as good and while items with values between 0.5 to 0.7 were found as less effective and removed. Thus, only suitable items were included in the final Achievement test. (**APPENDIX 3**)

## 7. Preparation of the Final Test

Out of the 45 draft items, 40 items were selected for the final Achievement test based on the discrimination power and difficulty index. The selected items were systematically arranged in the final test. (APPENDIX 4)

## 8. Structure of Test Items

After item analysis and validation, the final test consisted of **40 questions** distributed as follows

**Table 2**

*Structure of Test Items*

S. No.	Form of Questions	Number of Items	Total Marks
1	Multiple Choice Questions	20	20
2	Fill in the Blanks	5	5
3	True or False	10	10
4	Matching Items	5	5
	<b>Total</b>	<b>40</b>	<b>40</b>

## 9. Reliability and Validity of Test

The reliability of the Achievement Test was determined using **Cronbach's Alpha ( $\alpha$ )** method, which measures the internal consistency of the test items. This test was given to 20 students to perform an item analysis. The results showed that 40 of the items had mean values between **0.95 and 0.85**, suggesting that these questions were clear and well understood by the students. On the other hand, 5 of items (**Q22, Q24, Q26, Q28, and Q29**) had lower mean values, ranging from **0.59 to 0.79**, which indicated that these questions were a bit tricky.

As a result, those five items were dropped, leaving the final achievement test with **40 items**. Additionally, the reliability of the test was assessed using Cronbach's Alpha, which confirmed that the test had good internal consistency and reliability.

### **3.7.3 Phase I- Selection of PhET Simulations and Instructional Planning**

For the present study, PhET Interactive Simulations developed by the University of Colorado were used as the primary instructional tool to enhance students' conceptual understanding in Physics. These research-based and freely accessible simulations promote active, inquiry-based learning by allowing students to manipulate variables and observe outcomes. The topic "*Force and Motion*" from the Class VIII Kerala SCERT Science syllabus was selected, covering concepts such as types of forces, laws of motion, friction, and the relationship between force, mass, and acceleration. A structured lesson plan was developed aligning simulation activities with specific learning objectives and assessment tasks for each concept. **(APPENDIX 6)** Appropriate simulations were carefully chosen and integrated into instructional planning over a period of three weeks. Students actively engaged with the simulations through exploration, prediction, and observation, fostering a learner-centered approach to improve conceptual understanding.

### **3.7.4 Phase II- Experimental Design**

The Experimental phase of the study was designed to evaluate the Effectiveness of PhET simulation-based instruction in enhancing the conceptual understanding of Science among the high school students. An Achievement test was developed and standardized to assess the students understanding of the selected topic Force and Motion. The test included items measuring Knowledge, comprehension, and Application of concepts. The study adopted Quasi Experimental Design. The sample was divided into two groups:

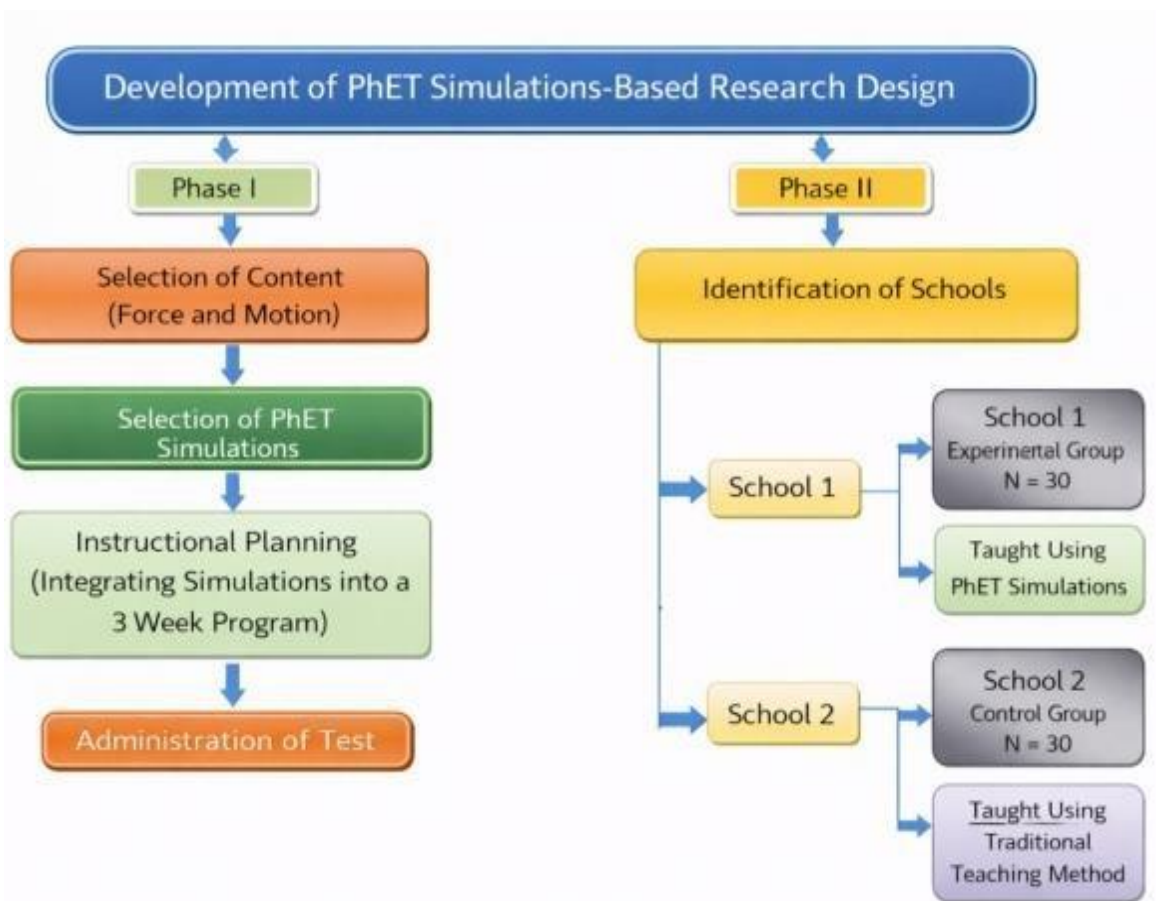
- **Experimental Group-** taught using PhET simulations
- **Control Group-** taught using Traditional teaching method

At the beginning of the study, a Pre-test was administered to both groups to assess their initial level of conceptual understanding, following the Pre-test the instructional intervention was carried out over a period of 3 weeks.

After the intervention period a Post-test was administered to both the groups using the same achievement test to measure the improvement in conceptual understanding. The Pre-test and Post-test scores were analyzed using appropriate statistical techniques to determine the Effectiveness of PhET simulation-based instruction.

**Figure 5**

***Development of PhET Simulation-based Research Design***



**3.7.5. Experimental Intervention procedure**

During the Intervention phase the students in the experimental group were taught using PhET simulation based instruction over a period of 3 weeks. The teaching involved the use of interactive simulations that allowed students to visualize abstract concepts, manipulate variables and actively engage in learning process enhancing the conceptual understanding. At the same time the control group was taught using conventional teaching method, which included lecture, textbook explanation and chalk and talk method. The teacher explained the concepts in traditional teaching without using digital simulations. This intervention was carried out for a period of three weeks, ensuring that both groups were exposed to the same content but through different instructional approaches. **(PLATE 1, APPENDIX 5)**

**PLATE 1**

**EXPERIMENTAL INTERVENTION USING PhET SIMULATIONS**



Figure 6

*3-Week Intervention Framework*

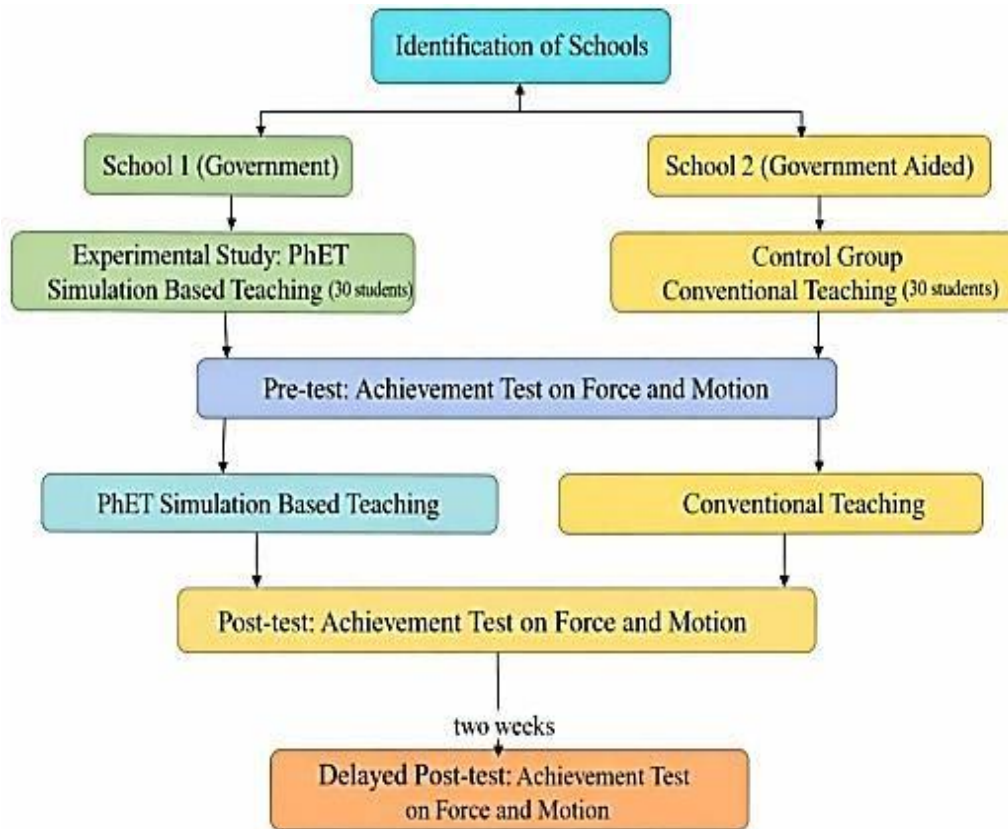
Week 1: Fundamentals of Force and Motion		
Topic	Topic	Activities & Outcomes
Day 1	Introduction to Force	• Forces & Motion Simulation, Push & Pull
Day 2	Balanced vs Unbalanced Forces	• Equal & Opposite Forces, No Motion vs Motion
Day 3	Types of Forces	• Contact & Non-Contact Forces • Applied Force vs Friction
Day 4	Motion and Acceleration	• Speed & Acceleration Changes
Day 5	Concept Reinforcement	• Mini Concept Test • Group Discussion
Week 2: Newton's Laws of Motion		
Day 6	Newton's First Law	• Inertia & Object at Rest
Day 7	Inertia and Mass	• Mass vs Motion Resistance
Day 8	Newton's Second Law (F= ma)	• Mass & Acceleration
Day 9	Mathematical Relationship	• F = ma Formula Practice
Day 10	Application & Problem Solving	• Real-Life Force Problems
Week 3: Friction and Integrated Concepts		
Day 11	Introduction to Friction	• Surface Types & Friction
Day 12	Static vs Kinetic Friction	• Static vs Moving Friction
Day 13	Factors Affecting Friction	• Mass, Surface & Friction
Day 14	Integrated Force Activities	• Design Your Own Experiment
Day 15	Concept Consolidation	• Review & Concept Mapping
Week 3: Friction and Integrated Concepts		
Day 11	Introduction to Friction	• Surface Types & Friction
Day 12	Static vs Kinetic Friction	• Static vs Moving Friction
Day 13	Factors Affecting Friction	• Mass, Surface & Friction
Day 14	Integrated Force Activities	• Design Your Own Experiment
Day 15	Concept Consolidation	• Review & Concept Mapping
Post-Test		
Assessment & Review		
Delayed Post-Test (After 2 Weeks)		

**3.7.6. Delayed Post –Test**

A Delayed Post-test was conducted 2 weeks after the completion of the intervention period to assess the retention of conceptual understanding among the students. The same Achievement test was administered to both the groups. This helped in evaluating the effectiveness of PhET Simulation-based instruction compared to conventional teaching method.

**Figure 7**

***Intervention Procedure***



**3.8. Feedback Form**

A structured feedback form was used as a data collection tool to assess students' perceptions of PhET simulation-based learning. Initially, 20 items were developed based on the objectives of the study and relevant literature. The tool was subjected to reliability analysis using Cronbach's alpha its yielded a value of **0.86** indicating good internal consistency, and items with low consistency were removed, resulting in a final set of 15 statements. The questionnaire was designed using a five-point Likert scale ranging from Strongly Disagree (SD) to Strongly Agree (SA). The items focused on student conceptual understanding, engagement, ease of use, and overall effectiveness of PhET simulations in learning force and motion. The feedback form is attached in the (**APPENDIX 7**).

### 3.9. Scoring and Analysis of Data

The responses of the students in the Achievement tests were scored using a Scoring key. Each correct answer was awarded 1 mark and incorrect answers were given 0 marks. The total scores obtained by the students in the Pre-test, Post-test, and Delayed Post-test were calculated separately.

### 3.10. Statistical Techniques used for the study

The collected data were consolidated tabulated and analyzed statistically by using the following tests.

#### 3.10.1. SPSS for Quantitative analysis

SPSS (Statistical Package for the Social Sciences) analysis involves using SPSS software to conduct the statistical analysis on data. It allows us to organize and manipulate data efficiently, perform complex statistical calculations and generate informative visualizations. Results obtained from SPSS analysis help researchers to draw conclusions, make prediction, and inform decision making processes.

Statistical techniques were used by the investigator are,

- Mean and Standard Deviation
  - Independent t-test (between groups)
  - Paired t-test (within groups)
  - Effect size Analysis
  - Gain score Analysis
  - Retention Analysis
  - Regression Analysis
- **Mean and Standard Deviation:** The investigator was calculated these to get the average performance and the variability in scores for both the experimental and control groups.

- **Independent t-test (between groups):** This test helped us to compare the Post-test scores of the experimental and control groups, allowing us to assess how effective the PhET Interactive simulation was.
- **Paired t-test (within groups):** The investigator used this test to look at the Pre-test and Post-test scores within each group, helping us identify any improvements in the students' achievements.
- **Effect size Analysis:** The investigator used this analysis to measure the magnitude of difference between the Pre-test and Post-test scores within each group, helping to understand how meaningful the improvement in students' achievement was.
- **Gain Score Analysis:** This test is used to calculate the gain scores by subtracting the Pre-test scores from the Post-test scores.
- **Retention Analysis (Delayed Post-test):** The investigator analyzed the Delayed Post-test scores to see how well students retained the concepts of Force and Motion after some time had passed.
- **Regression Analysis:** Regression analysis is a statistical technique used to examine the relationship between a dependent variable and one or more independent variables. It helps in understanding how the value of the dependent variable changes when the independent variables are varied. This method is widely used to predict outcomes and to determine the strength and direction of relationships between variables.

### 3.11. Conclusion

The Chapter 3 of the research report presents a comprehensive overview of the methodology adopted for data collection, including the tools used, administration protocols, and evaluation techniques. The chapter also discusses the statistical methods employed for data analysis. Subsequently, the data obtained was collected, analyzed, and interpreted in a Chapter 4, where findings of the study are presented in detail.



**ANALYSIS AND  
INTERPRETATION**

## CHAPTER IV

### ANALYSIS AND INTERPRETATION

#### 4.1. Introduction

The analysis and interpretation of data form the most crucial part of any investigation. This Process involves studying the collected and tabulated data to uncover meaningful patterns and Insights. It includes breaking down complex variables into simpler components and reorganizing them to support clear conclusions.

**The purpose of this analysis is three fold:**

- To convert raw data in to meaningful information
- To test the formulated hypotheses
- To derive significant and relevant findings

The present study aims to explore the Effectiveness of PhET Interactive simulations in enhancing the conceptual understanding the Science among High school students in the topic of Force and Motion.

Data were collected using a researcher developed Achievement test along with a suitable instructional intervention based on PhET simulations. The collected were analyzed using appropriate statistical techniques. The results are presented below along with their interpretations.

## SECTION I

### DESCRIPTIVE ANALYSIS

Descriptive analysis is a statistical method used to summarize and organize data in a meaningful way. It focuses on describing the main features of a data set through measures like frequency, percentage, mean, and standard deviation. This type of analysis helps in understanding patterns, trends, and distributions within the data.

#### 4.1.1. Descriptive Statistics of Pre-test scores of Experimental and Control Groups

Table below shows the Descriptive Statistics of Pre-test scores of Experimental and Control Groups

**Table 3**

#### *Descriptive Statistics of Pre-test scores of Experimental and Control Groups*

<b>Group</b>	<b>N</b>	<b>Mean</b>	<b>SD</b>	<b>Skewness</b>	<b>Kurtosis</b>
Experimental Group	30	13.067	2.227	-0.024	-0.459
Control Group	30	15.400	2.313	1.275	2.355

The table indicates that the control group ( $M = 15.4$ ) shows a higher mean Pre test score compared to the Experimental group ( $M = 13.06$ ), which shows a better level of previous knowledge. The standard deviation values for both the groups are nearly identical, implying comparable variability in their scores. The Skewness and Kurtosis values fall within the acceptable ranges, signifying that the data are normally distributed.

#### 4.1.2 Descriptive Statistics of Post-test scores of Experimental and Control groups

Table below shows the Descriptive Statistics of Post-test Scores of Experimental and Control groups

**Table 4**

##### *Descriptive Statistics of Post-test scores of Experimental and Control groups*

<b>Group</b>	<b>N</b>	<b>Mean</b>	<b>SD</b>	<b>Skewness</b>	<b>Kurtosis</b>
Experimental Group	30	21.334	4.179	1.166	1.297
Control Group	30	20.200	2.249	0.200	-1.127

The table indicates that the Experimental group ( $M = 21.34$ ) has a slightly higher mean Post- test score compared to the Control group ( $M = 20.20$ ), which shows a better performance after the Intervention. The Skewness and Kurtosis values fall within the acceptable ranges, signifying that the data are normally distributed. Overall, the result indicates improved performance in the Experimental group.

#### 4.1.3 Descriptive Statistics of Delayed Post-test scores of Experimental and Control groups

Table below shows the Descriptive Statistics of Delayed Post-test Scores of Experimental and Control groups

**Table 5**

##### *Descriptive Statistics of Delayed Post-test scores of Experimental and Control groups*

<b>Group</b>	<b>N</b>	<b>Mean</b>	<b>SD</b>	<b>Skewness</b>	<b>Kurtosis</b>
Experimental Group	30	21.034	4.522	1.281	1.496
Control Group	30	18.600	3.398	0.487	-0.337

The table shows that the Experimental group ( $M = 21.034$ ) scored higher than the Control group ( $M = 18.600$ ), indicating better retention. Skewness and Kurtosis values for both groups fall within acceptable ranges, suggesting normal distribution. Overall, the Experimental group demonstrates better retention than the Control group.

#### 4.1.4 Descriptive Statistics of Pre-test scores of Experimental and control groups based on Gender

Table below shows the Descriptive Statistics of Pre-test scores of Experimental and control groups based on Gender

**Table 6**

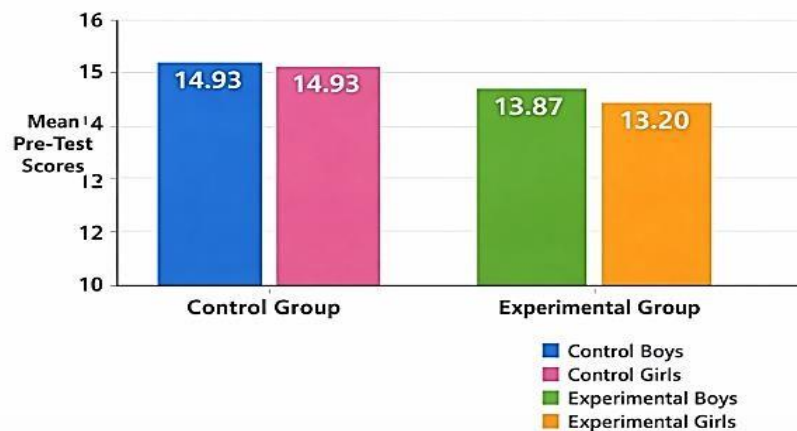
*Descriptive Statistics of Pre-test scores of Experimental and control groups based on Gender*

Group	Gender	N	Mean	SD	Skewness	Kurtosis
Control	Boys	15	14.93	2.22	0.13	-0.69
	Girls	15	14.93	2.91	0.15	-1.06
Experimental	Boys	15	13.87	1.88	1.19	1.91
	Girls	15	13.20	2.81	1.15	0.63

In the control group, boys and girls had identical mean scores (14.93), indicating similar baseline knowledge, with slightly higher variability among girls. In the experimental group, boys (13.87) scored slightly higher than girls (13.20). Skewness and Kurtosis values suggest that all distributions are approximately normal.

**Figure 8**

*Descriptive Statistics of Pre-test scores of Experimental and control groups based on Gender*



#### 4.1.5 Descriptive Statistics of Post-test scores of Experimental and control groups based on Gender

Table below shows the Descriptive Statistics of Post-test scores of Experimental and control groups based on Gender

**Table 7**

*Descriptive Statistics of Post-test scores of Experimental and control groups based on Gender*

Group	Gender	N	Mean	SD	Skewness	Kurtosis
Control	Boys	15	20.40	2.19	0.46	-0.73
	Girls	15	21.47	2.69	-0.10	-0.94
Experimental	Boys	15	20.27	3.35	0.43	-0.78
	Girls	15	21.80	5.04	1.64	3.02

The table presents the descriptive statistics of Post-test scores of experimental and control groups based on gender. Girls scored slightly higher than boys in both groups (Control: 21.47 vs 20.40; Experimental: 21.80 vs 20.27). Variability was highest among experimental group girls. Skewness and Kurtosis indicate mostly normal distributions, with experimental girls showing slight positive Skewness and a Leptokurtic pattern.

**Figure 9**

*Descriptive Statistics of Post-test scores of Experimental and control groups based on Gender*



#### 4.1.6 Descriptive Statistics of Delayed Post-test scores of Experimental and control groups based on Gender

Table below shows the Descriptive Statistics of Delayed Post-test scores of Experimental and control groups based on Gender

**Table 8**

*Descriptive Statistics of Delayed Post-test scores of Experimental and control groups based on Gender*

Group	Gender	N	Mean	SD	Skewness	Kurtosis
Control	Boys	15	20.13	3.54	0.52	-0.81
	Girls	15	18.67	3.14	0.36	-0.91
Experimental	Boys	15	19.20	3.69	0.77	-0.42
	Girls	15	20.53	5.21	1.71	3.38

The table shows the descriptive statistics of Delayed Post-test scores of experimental and control groups based on gender. In the control group, boys performed slightly better than girls. In contrast, in the experimental group, girls outperformed boys, though experimental girls exhibit higher positive Skewness and Kurtosis, indicating slight deviation from normality.

**Figure 10**

*Descriptive Statistics of Delayed Post-test scores of Experimental and control groups based on Gender*



#### 4.1.7 Descriptive Statistics of Pre-test scores for Experimental and Control group based on Interest branch in Science

Table below shows the Descriptive Statistics of Pre-test scores Experimental and Control group based on Interest branch in Science

**Table 9**

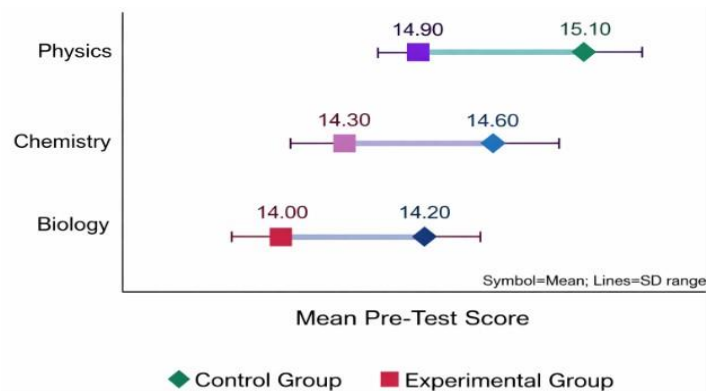
*Descriptive Statistics of Pre-test scores for Experimental and Control group based on Interest in Branch*

Group	Branch of Interest	N	Mean	SD	Skewness	Kurtosis
Control	Physics	12	15.10	2.20	0.10	-0.55
	Chemistry	10	14.60	2.50	0.25	-0.60
	Biology	8	14.20	2.40	0.40	-0.30
Experimental	Physics	8	14.90	2.10	0.15	-0.50
	Chemistry	9	14.30	2.60	0.30	-0.55
	Biology	13	14.00	2.50	0.45	-0.20

The findings indicate that Students interested in Physics scored highest in both groups, followed by Chemistry and Biology. Variability was moderate across all categories. Skewness indicates slight positive skew, while Kurtosis suggests a Platykurtic distribution. Overall, patterns are consistent with no major deviation from normality.

**Figure 11**

*Descriptive Statistics of Pre-test scores for Experimental and Control group based on Interest branch in Science*



#### 4.1.8 Descriptive Statistics of Post-test scores for Experimental and Control group based on Interest branch in Science

Table below shows the Descriptive Statistics of Post-test scores for Experimental and Control group based on Interest branch in Science

**Table 10**

*Descriptive Statistics of Post-test Scores for Experimental and Control group based on Interest in Branch*

Group	Branch of Interest	N	Mean	SD	Skewness	Kurtosis
Control	Physics	12	20.20	2.30	0.42	-0.48
	Chemistry	10	20.60	2.40	0.50	-0.30
	Biology	8	20.10	2.60	0.55	-0.20
Experimental	Physics	8	23.40	2.20	0.60	-0.10
	Chemistry	9	24.10	2.50	0.65	0.05
	Biology	13	24.50	3.00	1.10	2.00

In the control group, Chemistry scored highest, followed by Physics and Biology, while in the experimental group, Biology ranked highest, followed by Chemistry and Physics. The experimental group showed higher overall mean scores. Skewness indicates positive Skewness in both groups, and Kurtosis suggests mostly Platykurtic distributions, with Biology in the experimental group showing a Leptokurtic pattern.

**Figure 12**

*Descriptive Statistics of Post-test scores for Experimental and Control group based on Interest branch in Science*



#### 4.1.9 Descriptive Statistics of Delayed Post-test Scores for Experimental and Control group based on Interest in Branch

Table below shows the Descriptive Statistics of Delayed Post-test scores for Experimental and Control based on Interest in Branch

**Table 11**

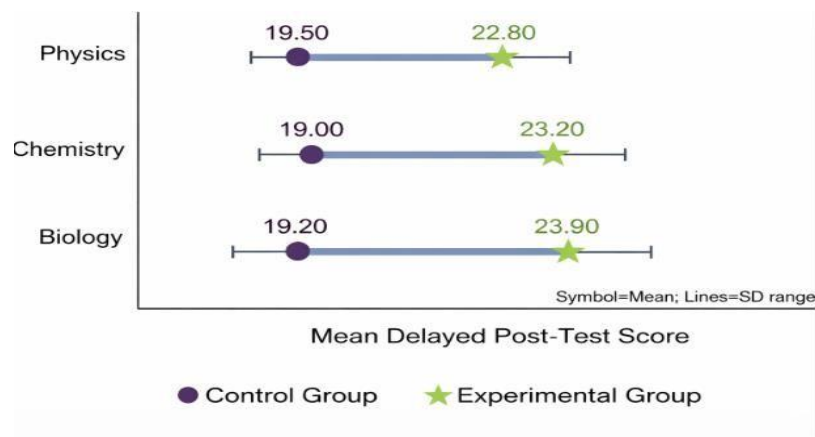
*Descriptive Statistics of Delayed Post-test scores for Experimental and Control based on Interest in Branch*

Group	Branch of Interest	N	Mean	SD	Skewness	Kurtosis
Control	Physics	12	19.50	3.00	0.60	0.05
	Chemistry	10	19.00	2.80	0.45	-0.35
	Biology	8	19.20	3.00	0.65	0.10
Experimental	Physics	8	22.80	3.10	0.80	0.70
	Chemistry	9	23.20	3.00	0.55	-0.05
	Biology	13	23.90	3.80	1.25	2.50

The findings show that in the control group Physics scored highest, followed by Biology and Chemistry. Experimental group Biology scored highest, followed by Chemistry and Physics. Overall, the experimental group performed better. The data show slight positive Skewness and mostly normal distribution, with Biology slightly more peaked.

**Figure 13**

*Descriptive Statistics of Delayed Post-test scores for Experimental and Control group based on Interest branch in Science*



#### 4.1.10 Descriptive Statistics of Pre-test scores for Experimental and Control group based on Science Achievement

Table below shows the Descriptive Statistics of Pre-test Scores for Experimental and Control group based on Science Achievement.

**Table 12**

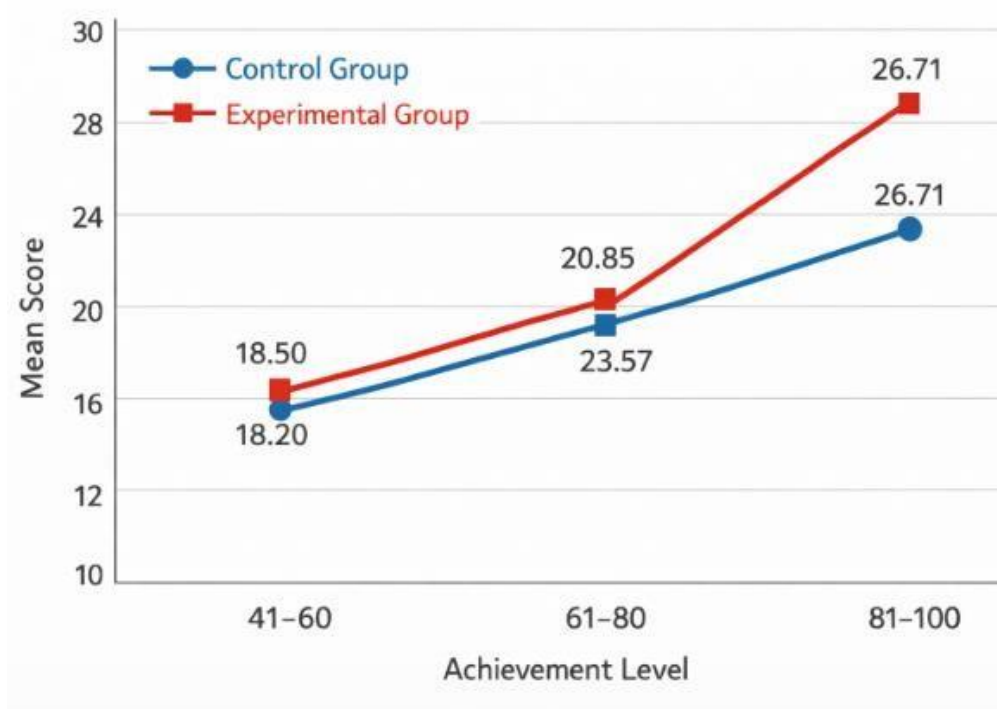
*Descriptive Statistics of Pre-test scores for Experimental and Control group based on Science Achievement*

Group	Achievement Level	N	Mean	SD	Skewness	Kurtosis
<b>Control</b>	41–60	8	18.50	1.10	0.28	-0.55
	61–80	15	20.40	1.85	0.36	-0.40
	81–100	7	23.57	2.10	0.42	-0.30
<b>Experimental</b>	41–60	9	18.20	1.25	0.40	-0.45
	61–80	13	20.85	1.95	0.48	-0.35
	81–100	8	26.71	3.80	0.60	0.20

The table shows a consistent increase in mean scores across achievement levels in both the control and experimental groups, indicating progressive improvement in performance. Although both groups follow a similar trend, the experimental group demonstrates comparatively higher achievement, especially at the highest level, suggesting the effectiveness of the intervention. The data also indicate slight positive Skewness and mostly Platykurtic distributions, reflecting moderate variability with minimal deviation from normality. Additionally, the results suggest that students in the experimental group benefited more in terms of conceptual understanding as they progressed to higher achievement levels.

**Figure 14**

*Descriptive Statistics of Pre-test scores for Experimental and Control group based on Science Achievement*



#### 4.1.11 Descriptive Statistics of Post-test scores for Experimental and Control group based on Science Achievement

Table below shows the Descriptive Statistics of Post-test scores for Experimental and Control group based on Science Achievement

**Table 13**

*Descriptive Statistics of Post-test scores for Experimental and Control group based on Science Achievement*

Group	Achievement Level	N	Mean	SD	Skewness	Kurtosis
Control	41–60	8	18.57	0.98	0.25	-0.60
	61–80	15	20.50	1.75	0.32	-0.45
	81–100	7	24.14	1.95	0.38	-0.30
Experimental	41–60	9	18.11	1.05	0.40	-0.50
	61–80	13	20.15	1.80	0.46	-0.40
	81–100	8	26.88	4.90	0.70	0.50

The table indicates that mean scores increase across achievement levels in both the control and experimental groups. While a similar trend is observed in both, the experimental group shows comparatively higher performance, especially at the highest achievement level. The data also reflect slight positive Skewness and mostly Platykurtic distributions, indicating moderate variability with minor deviation from normality.

**Figure 15**

*Descriptive Statistics of Post-test scores for Experimental and Control group based on Science Achievement*



#### 4.1.12 Descriptive Statistics of Delayed Post-test scores for Experimental and Control group based on Science Achievement

Table below shows the Descriptive Statistics of Delayed Post-test scores for Experimental and Control group based on Science Achievement

**Table 14**

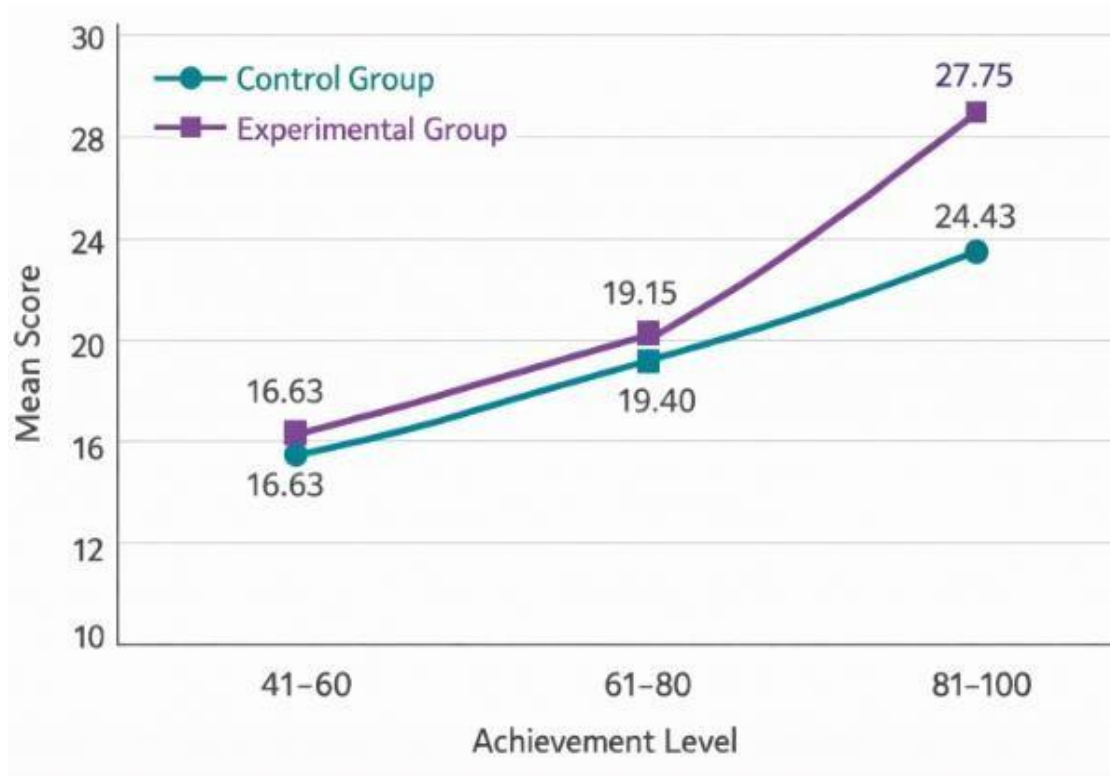
*Descriptive Statistics of Delayed Post-test scores for Experimental and Control group based on Science Achievement*

Group	Achievement Level	N	Mean	SD	Skewness	Kurtosis
<b>Control</b>	41–60	8	16.63	1.30	0.28	-0.55
	61–80	15	19.40	2.10	0.35	-0.40
	81–100	7	24.43	2.85	0.45	-0.25
<b>Experimental</b>	41–60	9	16.44	1.25	0.38	-0.50
	61–80	13	19.15	2.05	0.48	-0.35
	81–100	8	27.75	5.60	0.75	0.65

The table shows that mean scores increase across achievement levels in both the control and experimental groups, indicating progressive improvement in performance. While both groups follow a similar pattern, the experimental group demonstrates higher performance, particularly at the highest achievement level. The data also indicate slight positive Skewness and mostly Platykurtic distributions, suggesting moderate variability with minimal deviation from normality. Additionally, the results imply that the intervention was more effective in enhancing higher-order understanding among students in the experimental group.

**Figure 16**

*Descriptive Statistics of Delayed Post-test scores for Experimental and Control group based on Science Achievement*



## SECTION 2

### DIFFERENTIAL ANALYSIS

Differential analysis refers to a method of comparing two or more sets of data to identify differences or variations between them. It's often used to highlight what makes one group, condition, or scenario different from another.

The present study, differential analysis is used to compare the performance of students across different categories such as gender, interest in branch, and levels of science achievement in Pre-test, Post-test, and Delayed Post-test scores. This analysis helps in identifying whether these variables have any significant influence on student learning outcomes and retention. thereby supporting meaningful interpretation of the results and conclusions of the study.

#### 4.2.1. Comparison of Pre-test scores between Control and Experimental Groups using Independent t- test

Table below shows the Comparison of Pre-test scores between Control and Experimental Groups

**Table 15**

*Comparison of Pre-test scores between Experimental and Control Groups*

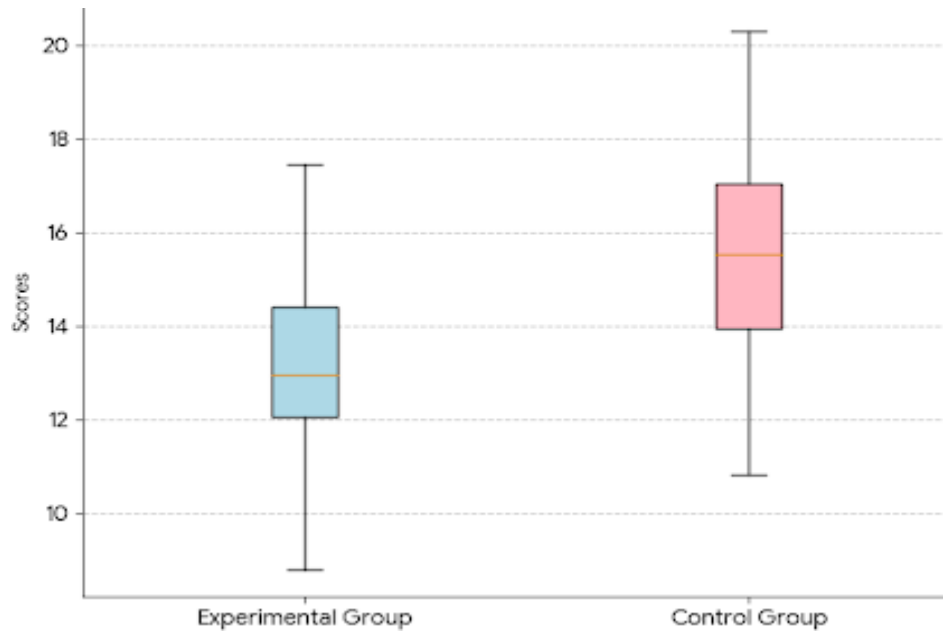
Group	N	Mean	SD	t-value	p-value	Significance
Experimental Group	30	13.0667	2.22731	3.980	0.498	NS
Control Group	30	15.4000	2.31338			

**NS = Non Significant**

The table shows that the control group (M = 15.4000, SD = 2.31338) has a higher mean Pre-test score than the experimental group (M = 13.0667, SD = 2.22731). However, the obtained p-value (.498) is greater than the 0.05 level of significance, indicating that the difference between the two groups is **not statistically significant**. This implies that both groups were almost equal in their prior knowledge before the intervention, ensuring a fair basis for comparison.

**Figure 17**

*Comparison of Pre-test scores between Experimental and Control groups*



#### 4.2.2. Comparison of Post-test scores between Control and Experimental groups using Independent t- test

Table below shows the Comparison of Post-test scores between Control and Experimental groups

**Table 16**

*Comparison of Post-test Scores between Experimental and Control groups*

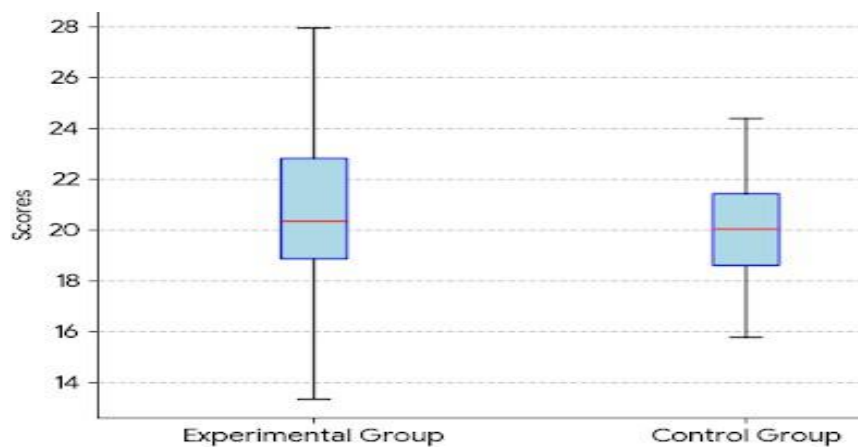
Group	N	Mean	SD	t-value	p-value	Significance
Experimental Group	30	21.3333	4.17985	1.308	0.02	S
Control Group	30	20.2000	2.24990			

**S = Significant**

The table indicates that the experimental group (M = 21.3333, SD = 4.17985) has a higher mean Post-test score than the control group (M = 20.2000, SD = 2.24990). The p-value (.002) is less than 0.05, showing that the difference is **statistically significant**.

**Figure 18**

*Comparison of Post-test scores between Experimental and Control groups*



### 4.2.3. Comparison of Delayed Pre-test scores between Control and Experimental groups using Independent t- test

Table below shows the Comparison of Delayed Post-test scores between Control and Experimental groups

**Table 17**

*Comparison of Delayed Post-test scores between Experimental and Control groups*

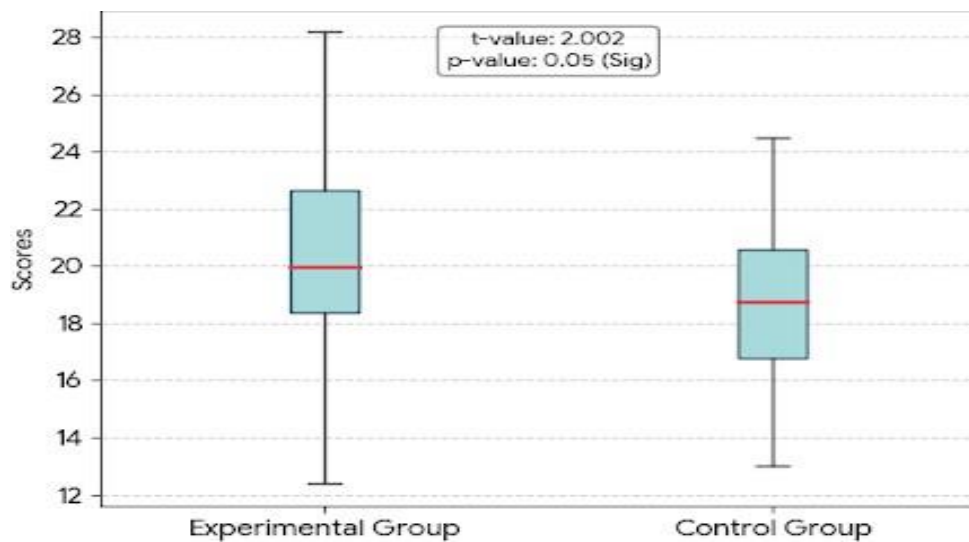
Group	N	Mean	SD	t-value	p-value	Significance
Experimental Group	30	21.0333	4.52185	2.002	0.05	S
Control Group	30	18.9244	3.0100			

**S = Significant**

The table shows that the experimental group (M = 21.0333, SD = 4.52185) has a higher mean Delayed Post-test score than the control group (M = 18.6000, SD = 3.39980). However, the p-value (.085) is greater than 0.05, indicating that the difference is **statistically significant**.

**Figure 19**

*Comparison of Delayed Post-test scores between Experimental and Control groups*



#### 4.2.4. Comparison of Pre-test and Post-test scores of the Experimental group using Paired t-test

Table below shows the Comparison of Pre-test and Post-test scores of the Experimental Group Using Paired t-test

**Table 18**

*Comparison of Pre-test and Post-test scores of the Experimental group using Paired t-test*

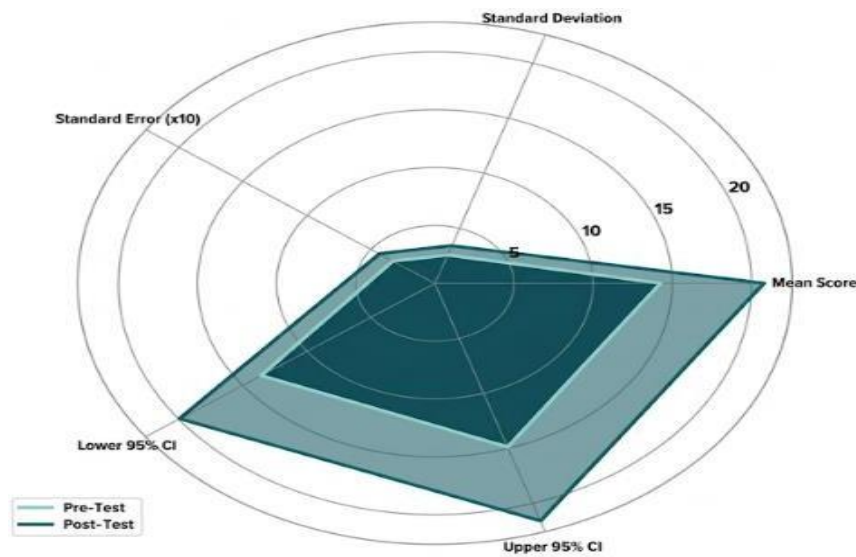
Test scores	N	Mean	SD	t-value	p-value	Significance
Pre-test scores	60	14.2333	2.54030	16.966	0.000	S
Post-test scores	60	20.7667	3.37672			

**S = Significant**

The table reveals a considerable increase in mean scores from Pre-test (M = 14.2333, SD = 2.54030) to Post-test (M = 20.7667, SD = 3.37672). The obtained p-value (.000) is less than 0.05, indicating that the difference is **statistically significant**. This clearly shows that the intervention brought about a significant improvement in students learning.

**Figure 20**

*Comparison of Pre-test & Post -test scores of the Experimental Group*



#### 4.2.5. Comparison of Post-test and Delayed Post-test scores of the Experimental group using Paired t-test

Table below shows the Comparison of Post-test and Delayed Post-test scores of the Experimental group using Paired t-test

**Table 19**

*Comparison of Post-test and Delayed Post-test Scores of the Experimental group using Paired t-test*

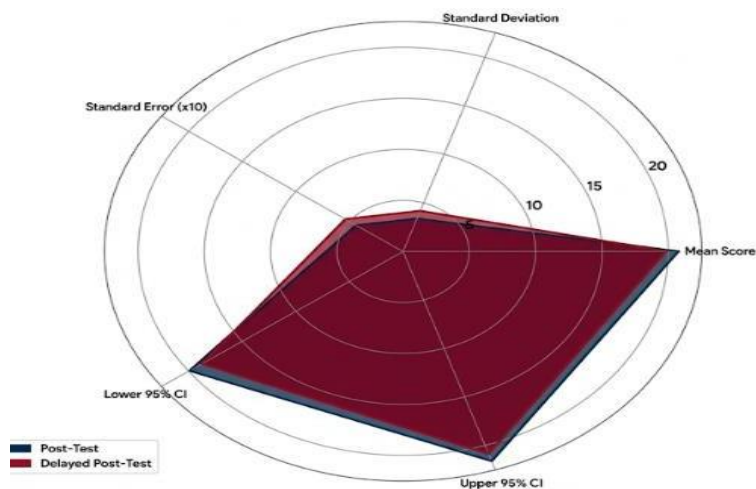
Test Scores	N	Mean	SD	t-value	p-value	Significance
Post-test scores	60	20.7667	3.37672	3.821	0.000	S
Delayed Post-test scores	60	19.8167	4.15175			

**S = Significant**

The table reveals a considerable increase in mean scores from Pre-test to Post-test. The obtained p-value (.000) is less than 0.05, indicating that the difference is **statistically significant**. This clearly shows that the intervention brought about a significant improvement in student learning.

**Figure 21**

*Comparison of Post-test & Delayed Post-test scores of the Experimental group*



#### 4.2.6. Comparison of Pre-test and Delayed Post-test Scores of the Experimental group using Paired t-test

Table below shows the Comparison of Pre-test and Delayed Post-test scores of the Experimental group using Paired t-test

**Table 20**

*Comparison of Pre-test and Delayed Post-test scores of the Experimental group using Paired t-Test*

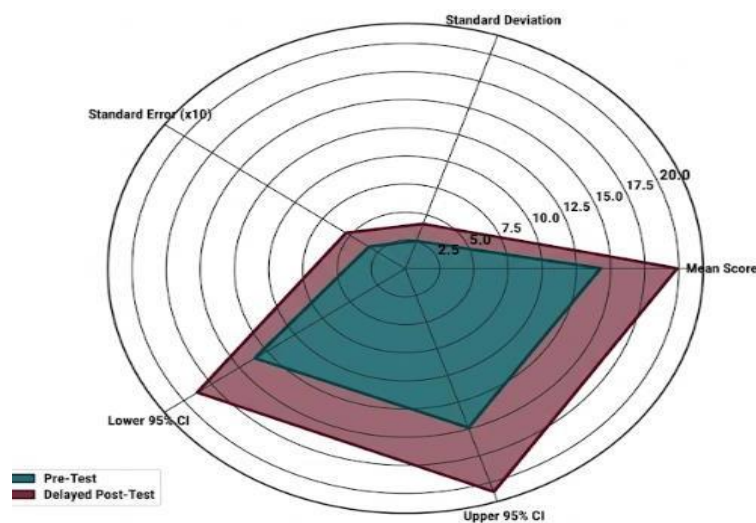
Group	N	Mean	SD	t-value	p-value	Significance
Pre-test scores	60	14.2333	2.54030	11.233	0.000	S
Delayed Post-test scores	60	19.8167	4.15175			

**S = Significant**

The table reveals a considerable increase in mean scores from Pre-test to Post-test. The obtained p-value (.000) is less than 0.05, indicating that the difference is **statistically significant**. This clearly shows that the intervention brought about a significant improvement in students learning.

**Figure 22**

*Comparison of Pre-test & Delayed Post -test scores of the Experimental group*



#### 4.2.7. Comparison of Gain Scores between Experimental and Control groups

Table below shows the Comparison of Gain Scores between Experimental and Control groups

**Table 21**

*Comparison of Gain Scores between Experimental and Control groups*

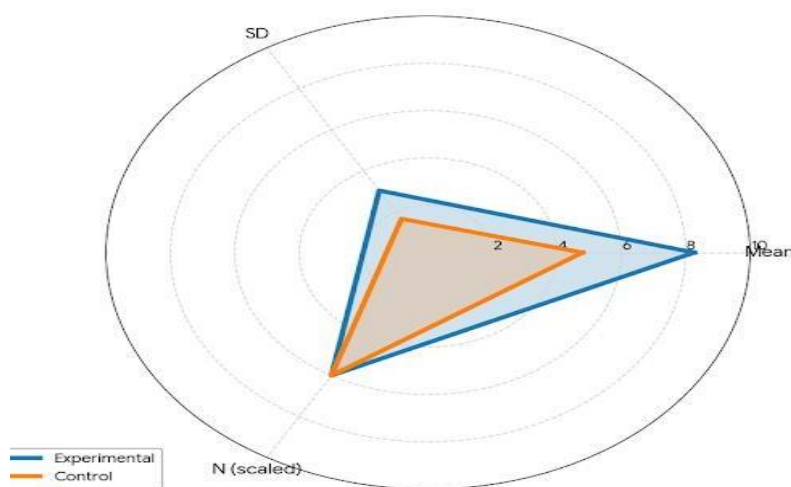
Group	N	Mean	SD	t-value	p-value	Significance
Experimental	60	8.2667	3.02784	5.508	0.000	S
Control	60	4.8000	1.64841			

**S = Significant**

The table shows that the experimental group has a considerably higher mean gain score than the control. The p-value (.000) is less than 0.05, indicating a **statistically significant difference**. This clearly demonstrates that the PhET simulation-based instruction was highly effective in enhancing students learning gains compared to the conventional teaching method.

**Figure 23**

*Comparison of Gain Scores between Experimental and Control groups*



#### 4.2.8 Comparison of Post test and Delayed Post-test scores in Force concepts between Control and Experimental groups

Table below shows the Comparison of Post-test and Delayed Post-test scores of control and Experimental groups in Force concept

**Table 22**

*Comparison of Post test and Delayed Post-test scores in Force concepts between Control and Experimental groups*

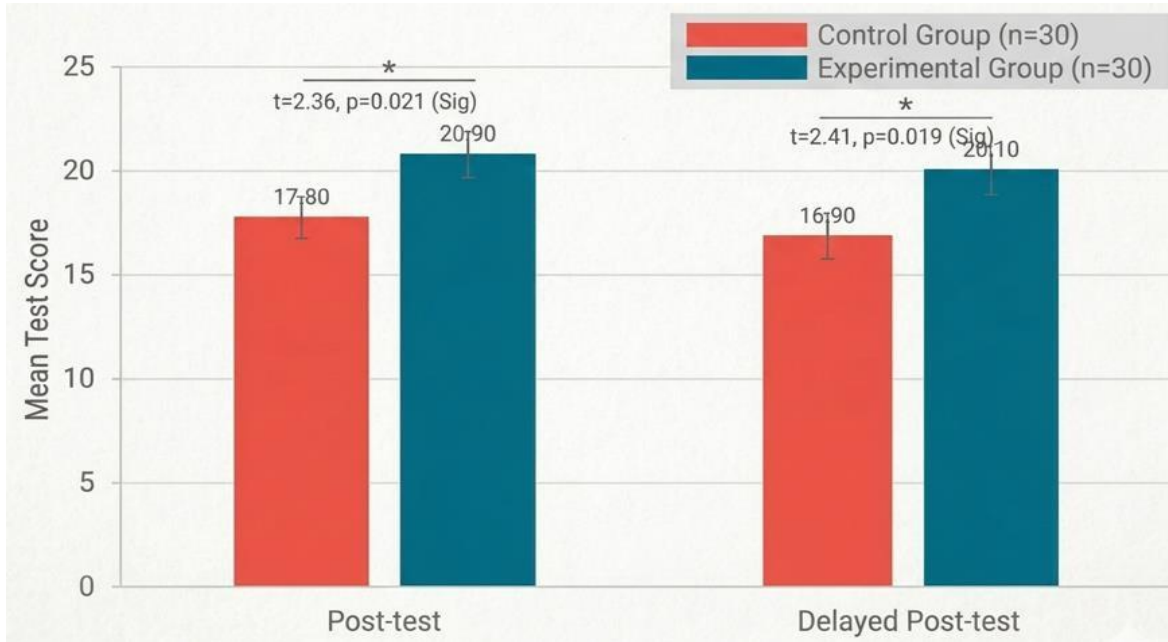
Test	Group	N	Mean	SD	t - value	P - value	Significance
Post – Test	Control	30	17.80	3.10	2.36	0.021	S
	Experimental	30	20.90	3.75			
Delayed Post- Test	Control	30	16.90	3.25	2.41	0.019	S
	Experimental	30	20.10	3.60			

**S = Significant**

The results reveal that the calculated t-values for the Force concept of both p-values are less than 0.05, the difference between the control and experimental groups is statistically significant. The **experimental group**, which was taught using **PhET simulation-based instruction**, obtained higher mean scores in both Post-test and Delayed Post-test compared to the control group. This indicates that PhET simulations are effective in enhancing students' conceptual understanding and also help in improving long-term retention of Force concepts.

**Figure 24**

*Comparison of Post test and Delayed Post-test scores in Force concepts between Control and Experimental groups*



#### 4.2.9 Comparison of Post test and Delayed Post-test scores in Motion concepts between Control and Experimental groups

Table below shows the Comparison of Pre-test and Delayed Post-test scores of control and Experimental groups in Motion concept

**Table 23**

*Comparison of Post test and Delayed Post-test scores in Motion concepts between Control and Experimental groups*

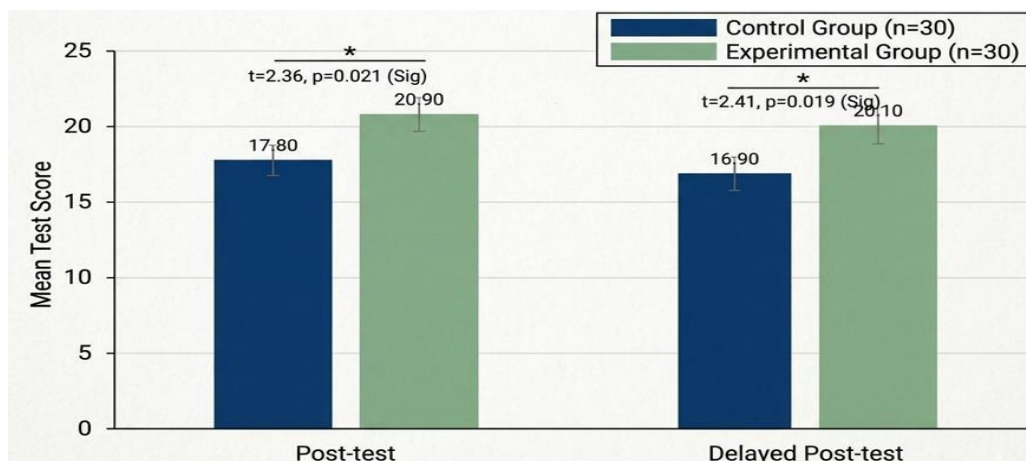
Test	Group	N	Mean	SD	t - value	P - value	Significance
Post - Test	Control	30	10.20	2.05	2.18	0.033	S
	Experimental	30	12.30	2.40			
Delayed Post- Test	Control	30	9.60	2.10	2.27	0.027	S
	Experimental	30	11.80	2.35			

**S = Significant**

The results reveal that the calculated t-values for the Motion concept both p-values are less than 0.05, the difference between the control and experimental groups is statistically significant.

**Figure 25**

*Comparison of Pre test and Delayed Post-test scores of Control and Experimental groups in Motion concept*



### SECTION 3

#### EFFECT SIZE ANALYSIS

In an experimental study, understanding effect size is key to grasping the real-world significance of findings, going beyond just statistical significance. While tests like the t-test or ANOVA can tell us if there's a difference between groups, effect size actually measures how big that difference is, giving us a clearer picture of how meaningful the results are in practical terms. Common effect size measures, such as Cohen's d, eta squared, or partial eta squared, assist researchers in determining whether an intervention has a small, moderate, or large effect. For example, in educational research, reporting effect size is vital for assessing the true effectiveness of teaching methods or interventions.

#### 4.3.1 Effect Size (Cohen's d) for the Difference in Post-test scores between Experimental and Control groups

**Table 24**

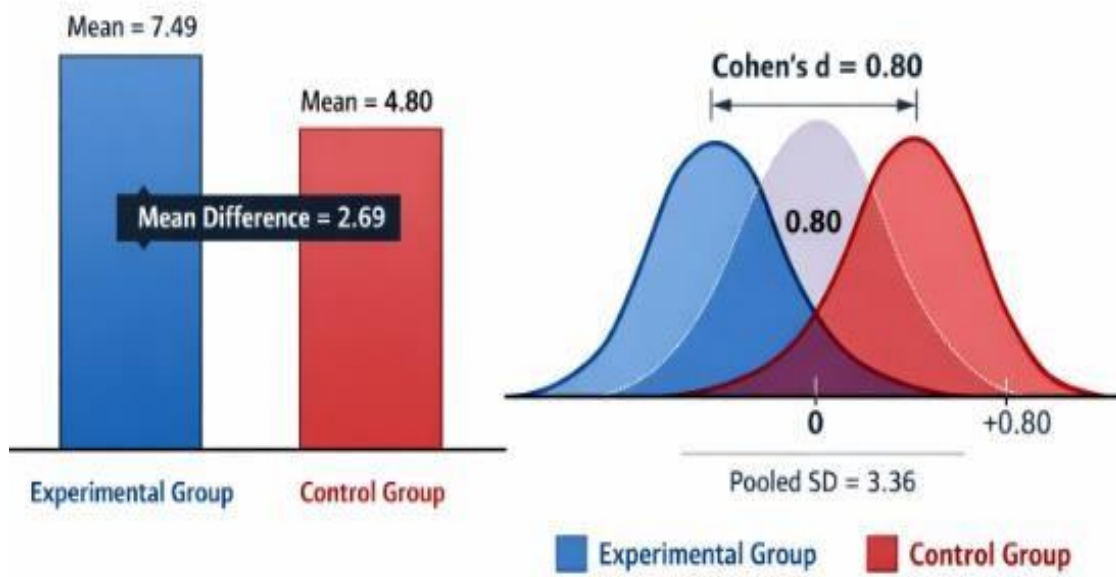
*Effect Size for the Difference in Post-test scores between Experimental and Control groups*

Group	N	Mean	SD	Mean Difference	Pooled SD	Cohen's d
Experimental	30	7.488	2.50	2.688	3.36	0.80
Control	30	4.800	1.50			

The table presents the effect size for the difference in Post-test scores between the experimental and control groups. The mean score of the experimental group is higher than that of the control group. The calculated Cohen's d value is **0.80**, which indicates a **highly effect size**. This suggests that the PhET simulation-based instruction had a **high impact** on student Post-test performance compared to the conventional teaching method. Although the difference is **statistically Significant**.

**Figure 26**

*Effect Size for the Difference in Post-test scores between Experimental and Control groups*



#### 4.2.2 Effect Size (Cohen's d) for the Difference in Gain scores between Experimental and Control groups

Table 25

*Effect Size for the Difference in Gain scores between Experimental and Control groups*

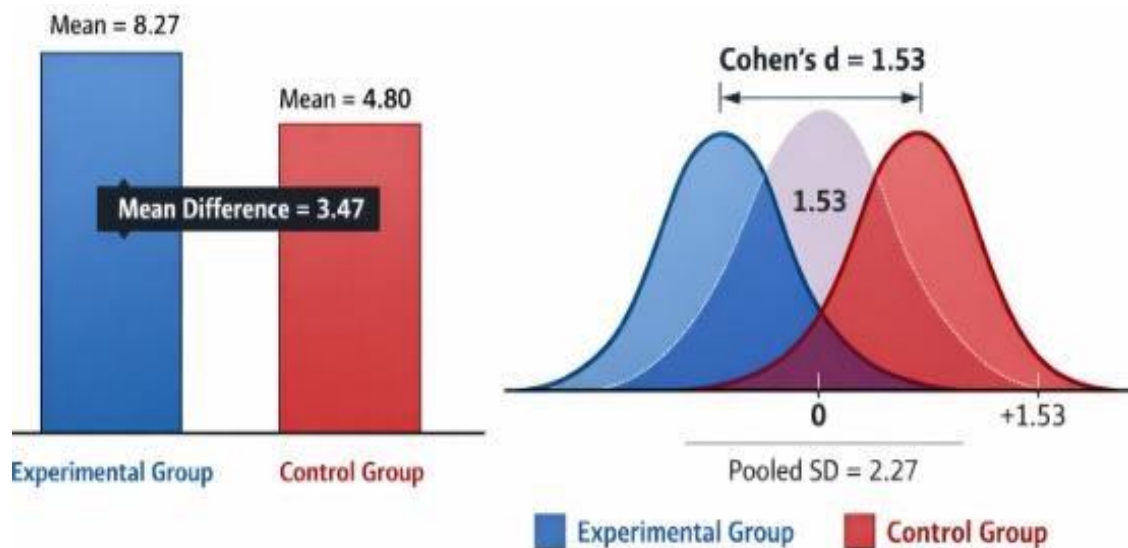
Group	N	Mean	SD	Mean Difference	Pooled SD	Cohen's d
Experimental	30	8.2667	2.9700	3.470	2.27	1.53
Control	30	4.8000	1.2000			

The table shows the effect size for the difference in gain scores between the experimental and control groups. The experimental group ( $M = 8.2667$ ,  $SD = 2.9700$ ) has a substantially higher mean gain score than the control group ( $M = 4.8000$ ,  $SD = 1.2000$ ).

The mean difference is 3.470, with a pooled standard deviation of 2.27. The obtained Cohen's d value is **1.53**, which indicates a **very large effect size**. This clearly shows that the PhET simulation-based instruction had a **strong and highly significant impact** on students learning gains. It demonstrates that the intervention was highly effective in improving students' conceptual understanding compared to the traditional method.

Figure 27

*Effect Size for the Difference in Gain scores between Experimental and Control groups*



### 4.3.3 Effect Size (Cohen's d) for Retention (Delayed Post-test) Scores between Experimental and Control groups

Table 26

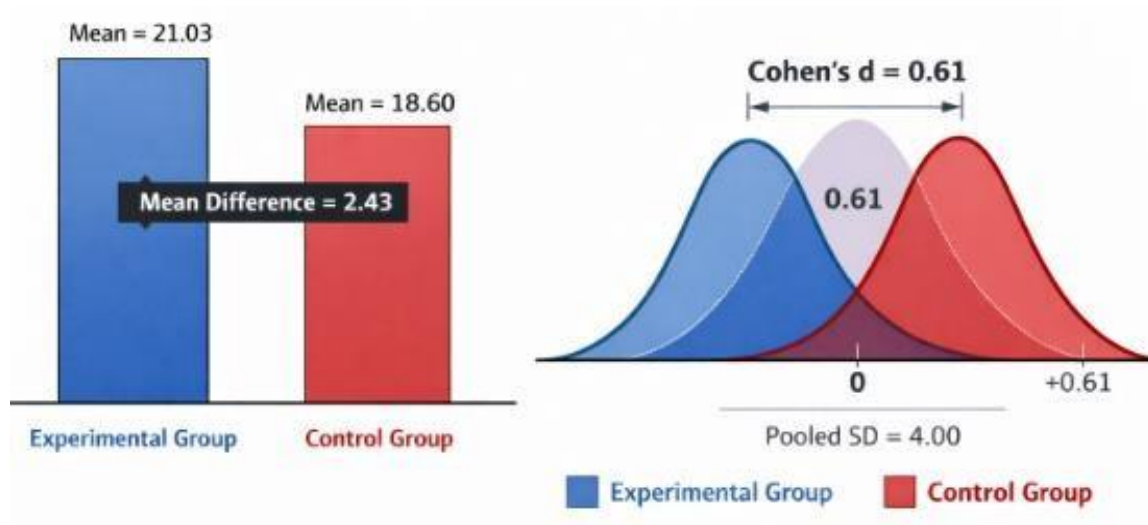
*Effect Size for the Retention scores between Experimental and Control groups*

Group	N	Mean	SD	Mean Difference	Pooled SD	Cohen's d
Experimental	30	21.030	4.5200	2.43	4.00	0.61
Control	30	18.600	3.4000			

The table presents the effect size for the difference in Delayed Post-test (retention) scores between the experimental and control groups. The mean score of the experimental group (M = 21.030, SD = 4.5200) is higher than that of the control group (M = 18.600, SD = 3.4000). The mean difference is 2.43, with a pooled standard deviation of 4.00. The calculated Cohen's d value is **0.61**, which indicates a **moderate effect size**.

Figure 28

*Effect Size for the retention scores between Experimental and Control groups*



## SECTION 4

### REGRESSION ANALYSIS

Regression analysis is a statistical technique used to examine the relationship between a dependent variable and one or more independent variables. It helps in understanding how the value of the dependent variable changes when the independent variables are varied. This method is widely used to predict outcomes and to determine the strength and direction of relationships between variables.

#### 4.4.1 Multiple Regression Analysis of Post-test scores Based on Pre-test and Delayed Post-test scores

Table 27

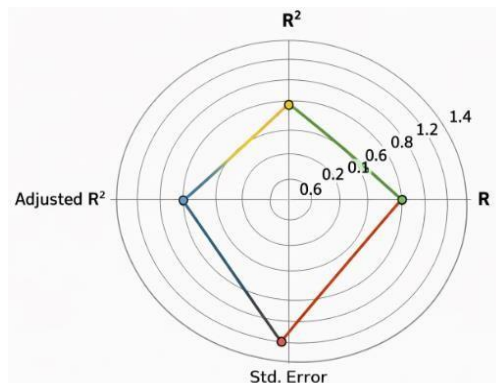
*Multiple Regression Analysis of Post-test scores Based on Pre-test and Delayed Post-test scores*

R	R <sup>2</sup>	Adjusted R <sup>2</sup>	Std. Error
0.904	0.817	0.811	1.468

The multiple regression analysis reveals a strong relationship between the predictors and Post-test scores ( $R = 0.904$ ). The model explains 81.7% of the variance ( $R^2 = 0.817$ ; Adjusted  $R^2 = 0.811$ ), indicating high explanatory power. The low standard error (1.468) shows good prediction accuracy. Overall, Pre-test and Delayed Post-test scores are strong predictors of Post-test performance.

Figure 29

*Multiple Regression Analysis of Post-test scores Based on Pre-test and Delayed Post-test scores*



#### 4.4.2 Analysis of Variance (ANOVA) for the Multiple Regression Model Predicting Post-test scores

**Table 28**

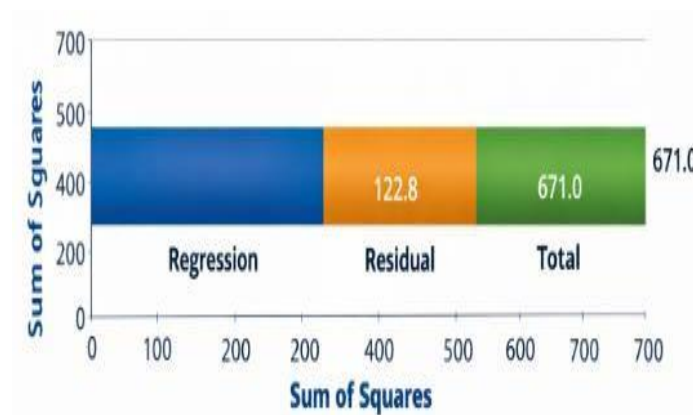
*Analysis of Variance (ANOVA) for the Multiple Regression Model Predicting Post-test scores*

Source	SS	Df	MS	F	p-value
Regression	548.20	2	274.10	127.15	0.000
Residual	122.80	57	2.155		
Total	671.00	59			

The ANOVA table shows the overall significance of the regression model used to predict Post-test scores. The regression sum of squares (SS = 548.20) is much higher than the residual sum of squares (SS = 122.80), indicating that a large portion of the variation in Post-test scores is explained by the model. The F-value (F = 127.15) is very high, and the corresponding p-value (0.000) is less than 0.05, indicating that the regression model is **statistically significant**. This means that the predictors (Pre-test and Delayed Post-test scores) together significantly predict the Post-test scores. Thus, the regression model is a **good fit** for the data and can be considered reliable for explaining and predicting student Post-test performance.

**Figure 30**

*Analysis of Variance (ANOVA) for the Multiple Regression Model Predicting Post-test scores*



#### 4.5. Students Perceptions of PhET Simulations in Learning Force and Motion

The table below shows the Students Perceptions of PhET Simulations in Learning Force and Motion

**Table 29**

*Students' Perceptions of PhET Simulations in Learning the concepts of Force and Motion*

S. No.	Statements	SD		D		N		A		SA	
		N	%	N	%	N	%	N	%	N	%
1	PhET simulations helped me understand the concept of force clearly	1	3.3	2	6.7	3	10.0	12	40.0	12	40.0
2	PhET simulations improved my understanding of motion concepts	1	3.3	2	6.7	4	13.3	11	36.7	12	40.0
3	I was able to visualize force and motion better using the simulations	0	0.0	2	6.7	3	10.0	13	43.3	12	40.0
4	The simulations made abstract concepts easier to understand	1	3.3	1	3.3	4	13.3	12	40.0	12	40.0
5	I could easily observe the effect of changing variables	0	0.0	2	6.7	3	10.0	14	46.7	11	36.7
6	PhET helped me understand the relationship between force and motion	1	3.3	2	6.7	3	10.0	13	43.3	11	36.7
7	I was able to learn at my own pace using the simulations	1	3.3	3	10.0	5	16.7	11	36.7	10	33.3
8	The simulations made learning more interesting and engaging	0	0.0	1	3.3	3	10.0	13	43.3	13	43.3
9	I felt actively involved while learning through PhET simulations	1	3.3	2	6.7	4	13.3	12	40.0	11	36.7
10	The simulations helped me retain concepts for a longer time	1	3.3	2	6.7	5	16.7	12	40.0	10	33.3
11	I was able to apply concepts learned to solve problems	1	3.3	3	10.0	5	16.7	11	36.7	10	33.3
12	PhET helped me clear my misconceptions	1	3.3	2	6.7	4	13.3	13	43.3	10	33.3
13	I found the simulations easy to use and operate	0	0.0	2	6.7	3	10.0	14	46.7	11	36.7
14	I prefer simulations over traditional teaching	1	3.3	3	10.0	4	13.3	11	36.7	11	36.7
15	Overall, PhET enhanced my understanding of force and motion	0	0.0	1	3.3	3	10.0	13	43.3	13	43.3

The table indicates that a majority of students expressed agreement and strong agreement with all statements, reflecting a positive perception of PhET simulation-based learning. Very few students chose disagreement options, showing minimal negative responses. The results highlight that PhET simulations effectively enhanced student conceptual understanding, engagement, and interest in learning force and motion. Overall, the feedback suggests that the simulation-based method was highly effective and well-received by the students.

#### **4.6. Conclusion**

This chapter presented the analysis and interpretation of the collected data using appropriate statistical methods. The Pre-test results showed that both the control and experimental groups were almost equal at the beginning, ensuring similarity between the groups. Further analysis revealed that the experimental group performed better than the control group after the treatment, showing the effectiveness of the intervention. Both boys and girls benefited from the strategy, with only slight differences in their performance. Overall, the results support the research hypotheses and show that the experimental method had a positive effect on student achievement, providing a basis for the conclusions in the next chapter.



**FINDINGS AND  
CONCLUSION**

## CHAPTER V

### SUMMARY AND CONCLUSION

#### 5.1 Introduction

This chapter aims to provide an overview of the research findings and draw meaningful insights from the data collected. An attempt has been made to discuss the major findings of the study through new light on the unique findings and also to suggest comprehensive ways and means of utilizing the present information.

#### 5.2 Major Findings of the study

- In the Pre-test ,the control group  $M = 15.40, SD = 2.31$  outperformed the experimental group  $M = 13.07, SD = 2.23$ , But the difference wasn't statistically significant  $p > 0.05$  this suggests the both groups had nearly the same level of prior knowledge ,which means any improvements seen later can be credited to the intervention rather than initial disparities.
- The Skewness and Kurtosis values for both groups fell within acceptable range, indicating that the scores were normally distributed. This implies that the data didn't have extreme variations, making it suitable for parametric statistical methods and boosting the reliability of the findings.
- In the post –test, the experimental group  $M = 21.33, SD = 4.18$  achieved higher mean scores than the control group  $M = 20.20, SD = 2.25$ , and this difference was statistically significant  $p < 0.05$  .this clearly show that the intervention, specifically the PhET simulation –based instruction, positively influenced students understanding of concepts and their academic performance .
- During the delayed post –test, the experimental group  $M = 21.03, SD = 4.52$  outperformed the control group  $M = 18. SD = 3.40$ , it suggesting better retention of learning. It indicates that the intervention helped students hold onto concepts more effectively over time compared to traditional technical teaching methods.
- Gender wise analysis in the per-test results by gender revealed that boys and girls in the control group had the same mean scores ( $M=14.93$ ).In the experimental

group, boys (M=13.87) slightly outperformed girls (M= 13.20) .This shows that both genders began with nearly equal academic readiness, ensuring a fair basis future comparisons.

- In the post–test, girls in both groups outperformed boys (Control: Girls M=21.47 > Boys M=20.40; Experimental: Girls M=21.80 > Boys M=20.40; Experimental: Girls M=21.80> Boys M=20.27). This suggests that female students responded more effectively to the learning environment, particularly the interactive and responded more visual nature of the intervention.
- In the Delayed Post-test, boys in the control group performed better than girls, whereas in the experimental group girls (M=20.53) outperformed boys (M= 19.20). This indicates that the intervention may contributed to better to long-term retention among female students, possibly due to higher engagement levels.
- Analysis based on interest in science branches showed that students interested in Physics had higher Pre-test scores (Control: M=15.10; Experimental: M=14.90), suggesting that prior interest plays a role in initial academic performance.
- In the Post-test, the experimental group showed significantly higher mean scores across all branches (Physics: 23.40, Chemistry: 24.10, Biology: 24.50) compared to the control group. This indicates that the intervention was effective across difference subject interests and not limited to a particular branch.
- In the Delayed Post-test the experimental group continued to maintain higher score across all branches, indicating that the intervention not only improved learning but also supported long-term retention of knowledge across disciplines.
- Analysis based on achievement levels revealed a consistent increase in mean scores with higher achievement levels in both groups. This indicates that students with stronger academic backgrounds tend to perform better, but the intervention further enhances their performance.
- In the Post-test, the experimental group at the highest achievement level (M=26.88) performed better than the control group (M=24.14), showing that the intervention was particularly effective for high-achieving students by enhancing by enhancing their conceptual depth.

- In the Delayed Post-test, the experimental group ( $M=27.75$ ) again outperformed the control group ( $M =24.43$ ), indicating that high achievers in the experimental group were able to retain learning more effectively over time.
- The independent t-test for Pre-test scores ( $p =0.498 >0.05$ ) confirmed that there was no significant difference between the groups before the intervention, ensuring internal validity of the study.
- The independent t-test for post –test scores ( $p<0.05$ ) indicated a significant difference between the groups, clearly demonstrating that the instructional intervention was effective in improving student performance.
- The Delayed Post-test comparison showed better performance of the experimental group though not statistically strong, suggesting that while retention improved, it may require longer or repeated interventions for stronger impact.
- The paired t-test showed a highly significant improvement from per-test ( $M=14.23$ ) to post –test ( $M=20.77$ ) in the experimental group ( $p=0.000$ ), indicating that the intervention resulted in substantial learning gains
- A highly significant improvement form per-test to delayed post –test ( $M=19.82$ ) indicates that the knowledge gained was retained over time reflecting the effectiveness of the teaching method
- The significant difference between post –test and delayed post –test scores shows a slight decline in retention, which is natural over time but the scores still remained significantly higher than the per-test, indicating sustained learning.
- Gain score analysis showed that the experimental group ( $M =8.27$ ) had significantly higher gains than the control group ( $M =4.80$ ), confirming that the intervention double the learning improvement compared to traditional teaching.
- The effect size for post –test scores (Cohen’s  $d =0.80$ ) indicated a large effect, meaning the intervention had strong practical significance beyond statistical results.
- The effect size for gain scores (Cohen’s  $d =1.53$ ) indicated a very large effect highlighting that the instruction strategy had a power impact on Students learning progress.

- The effect size for retention scores (Cohen's  $d = 0.61$ ) indicate a moderate effect, suggesting that the intervention had a meaningful and educationally important influence on long-term retention
- Regression analysis showed a strong positive relationship ( $R = 0.904$ ) between Pre-test, Post-test, and Delayed Post-test scores, indicating consistency in student performance across different stages.
- The coefficient of determination ( $R^2 = 0.817$ ) revealed that 81.7% of the variation in Post-test scores was explained by Pre-test and Delayed Post-test scores, demonstrating high predictive strength of the model.
- The regression model was statistically significant ( $F = 127.15$ ,  $p = 0.000$ ), confirming that the predictors used in the study were reliable and meaningful in explaining student performance.
- Most students showed agreement and strong agreement with all the statements, indicating a positive view of PhET simulation-based learning. Very few students gave negative responses. The findings show that PhET simulations improved students understanding, engagement, and interest in learning force and motion. Overall, the method was effective and well accepted by students.
- Overall, the findings strongly establish that PhET simulation based instruction is highly effective in enhancing student conceptual understanding improving academic achievement, and promoting retention of learning, making it a superior alternative to conventional teaching methods.

### **5.3 Educational Implications**

- The study highlights the importance of integrating technology-based tools like PhET simulations in physics classrooms to enhance students' conceptual understanding.
- It suggests that simulation-based learning can effectively replace or supplement traditional teaching methods, making abstract concepts more concrete and understandable.

- The findings emphasize the need for student-centered and inquiry-based approaches, where learners actively explore and construct knowledge.
- The study indicates that using simulations can help in identifying and correcting misconceptions, especially in complex topics like force and motion.
- It supports the inclusion of digital learning resources in the curriculum, promoting interactive and experiential learning environments.

#### **5.4. Recommendations**

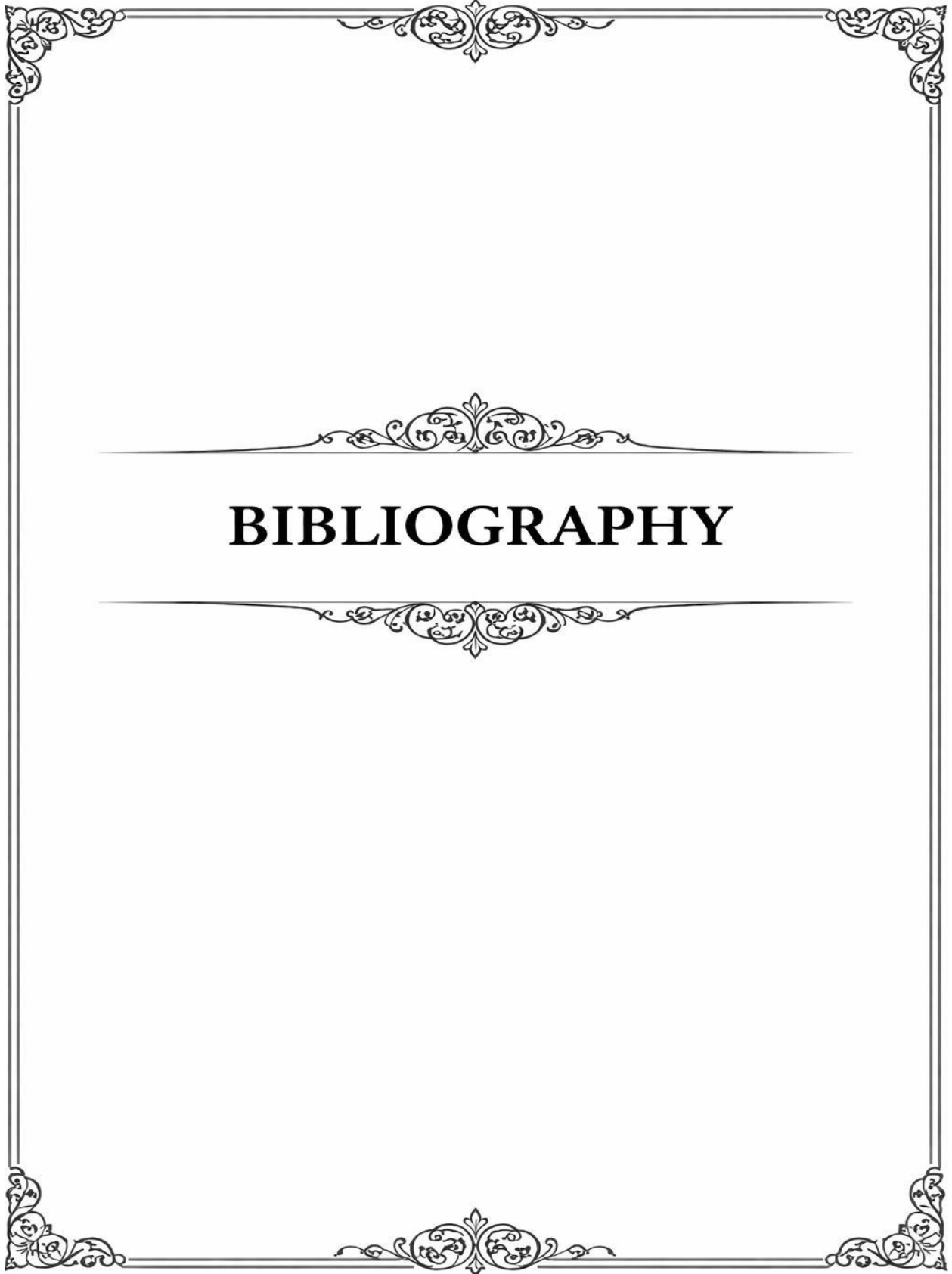
- It is recommended that PhET simulation based instruction is widely used in physics classrooms because it really boosts students understanding of concepts and their academic performance compared to the usual teaching methods.
- Teacher Education programs should definitely include training on how to use digital tools like PhET simulations, so teachers can seamlessly weave technology into their teaching practices.
- Schools also need to invest in solid ICT infrastructure think computers, internet access, and projectors to make sure simulation-based learning runs smoothly.
- Curriculum developers ought to weave simulation-based activities into textbooks and instructional materials, especially for those tricky concepts, to help clarify and enhance understanding.
- A blended teaching approach that mixes traditional methods with simulation-based instruction can really cater to different learning styles and improve overall effectiveness.
- Teachers should strive to create student-centered learning environments where students can dive into simulations, explore concepts on their own, and build a deeper understanding of the material.
- Regular feedback and assessment mechanisms should be integrated along with simulation-based instruction to monitor student progress and enhance learning outcomes.

## 5.5. Suggestions for further Research

- The study suggests that PhET simulations be particularly useful for teaching challenging concepts in force and motion, as students often struggle with abstract ideas. The engaging and interactive nature of these simulations can really clarify these concepts and enhance understanding.
- The study also suggests pairing guiding worksheets with the simulations, as structured activities can help focus student attention on the key learning objectives. This approach minimizes random exploration and ensures that students effectively reach the desired learning outcomes.
- Conducting simulation activities in small groups is another suggestions, as group learning fosters discussion, idea sharing, and peer support. This collaborative method can assist students in correcting misconceptions and deepening their understanding the concepts.
- Before diving into the simulations, it is a good idea to provide a brief orientation session so that students can get comfortable with the tools and controls. This preparation saves time during the lesson and allows students to concentrate more on learning instead of figuring out how to navigate the simulation.
- After the simulation activities, the study recommends holding discussion or reflection sessions where students can share their observations and clear up any doubts. This practice reinforces learning and helps with long term retention of the concepts.
- The study suggests incorporating simulations regularly throughout different lessons instead of just as a one-off activity. Continuous exposure to simulation-based learning can enhance retention, reinforce concepts, and make learning experience more engaging over time.

## **5.5 Conclusion**

The study concludes that PhET simulation-based instruction is more effective than traditional teaching in improving students conceptual understanding of force and motion. The experimental group showed higher achievement and better retention of concepts compared to the control group. The findings clearly indicate that the use of interactive simulations enhances learning and engagement. Hence, integrating PhET simulations in classroom teaching can significantly improve the quality of physics education.



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<http://www.physics.indiana.edu/~sdi/ajpv3i.pdf>

<https://nap.nationalacademies.org/catalog/9596>

<https://nap.nationalacademies.org/catalog/13165>

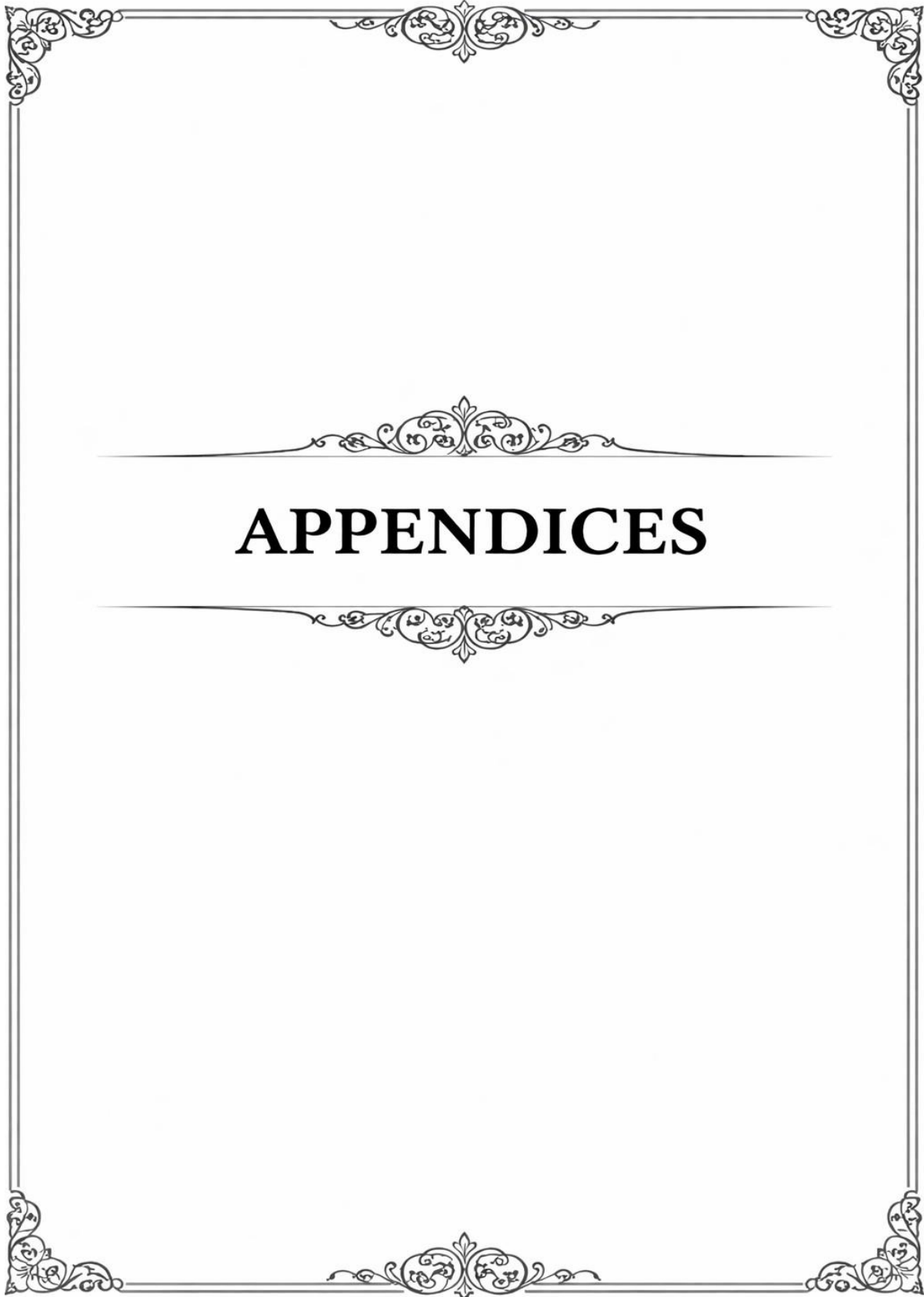
<https://phet.colorado.edu>

<https://doi.org/10.1119/1.2150754>

<https://doi.org/10.1103/PhysRevSTPER.4.010107>

<https://doi.org/10.1002/sce.3730660207>

[https://www.education.gov.in/sites/upload\\_files/mhrd/files/NEP\\_Final\\_English\\_0.pdf](https://www.education.gov.in/sites/upload_files/mhrd/files/NEP_Final_English_0.pdf)



**APPENDICES**

## Institutional Human Ethical Committe



Avinashilingam Institute for Home Science and Higher Education for Women  
Deemed-to-be-University Estd. u/s 3 of UGC Act 1956, Category A by MHRD (now MoE)  
Re-accredited with 'A++' Grade by NAAC CGPA 3.65/4, Category I by UGC  
Coimbatore-641 043, Tamil Nadu, India  
**Institutional Human Ethics Committee (IHEC)**

Date 4/3/2026

### Chairman

**Dr. Sudha Ramalingam**

Director, Research and Innovation  
Professor, Community Medicine  
PSG Institute of Medical Sciences  
& Research, Coimbatore

### To

Nandhini P  
24PED009  
Department of Education  
Avinashilingam Institute for Home Science and  
Higher Education for Women, Coimbatore 641043

### Member Secretary

Dr. Shubashini K. Sripathi  
Professor of Chemistry  
School of Physical Sciences and  
Computational Sciences

### Dear Ms Nandhini P

Ref: Your application IHEC 2026/EDN5  
Effectiveness of PhET Simulations in Enhancing Conceptual  
Understanding of Science among High School Students in  
Palakkad District, submitted for approval of IHEC

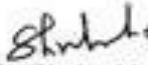
### Members

Thiru J.V. Raj (Legal Expert)  
Dr.C.Madhan Mohan (Medical Officer)  
Dr. S. Ganthimathi (Internal Expert)  
Dr. K Sambath Rani (Internal Expert)  
Dr. Vanithamani (Internal Expert)  
Dr. S.Gayathridevi (Internal Expert)  
Dr. Pa.Rajeswari (Internal Expert)  
Dr. S.Srividya (Internal Expert)  
Dr. M.Priya (Internal Expert)  
Mrs. M.Priya (Lay Person)

The Institutional Human Ethics Committee of Avinashilingam  
Institute for Home Science and Higher Education for Women  
after careful scrutiny and review of your application, hereby  
grants approval to your application titled 'Effectiveness of  
PhET Simulations in Enhancing Conceptual Understanding of  
Science among High School Students in Palakkad District.'. The  
approval number for the same is IHEC 2026/EDN5/  
XMT

This certificate is issued for the study period specified in your  
application.

Best Wishes,

  
**Dr. Shubashini K. Sripathi**  
Member Secretary



**APPENDIX 1**  
**DEMOGRAPHIC AND PERSONAL DATA SHEET**

**NAME OF THE STUDENT:** \_\_\_\_\_ **CLASS:** \_\_\_\_\_

1. Gender:

Male

Female

2. School type:

Government

Government- aided

3. Parental Education Level:

Father: \_\_\_\_\_ Mother: \_\_\_\_\_

4. Socio economic Status (SES):

Low income

Middle income

High income

5. Parental Occupation:

▪ Father: \_\_\_\_\_ Mother: \_\_\_\_\_

6. Previous exposure to PhET Simulation based Instruction

Yes

No

7. Interest in branch of science  Physics  Chemistry  Biology

8. Science Achievement (Last Exam Score):

• \_\_\_\_\_ (Specify percentage or GPA)

9. Frequency of Technology use in Science classes

Rare

Sometimes

Often

10. Previously used method to Teach Science

Lecture method

Demonstration

Activity based

## APPENDIX 2

### ACHIEVEMENT TEST TOOL BEFORE PILOT STUDY

CLASS: VIII

MARKS: 45

#### SCIENCE: PHYSICS- FORCE AND MOTION

#### I CHOOSE THE CORRECT ANSWER: 1x20=20

1. A force can change the \_\_\_\_\_ of an object.  
a) colour b) shape c) smell d) taste
2. The SI unit of force is  
a) metre b) kilogram c) newton d) second
3. Which of the following is a contact force  
a) Gravity b) Magnetic force c) Friction d) Electrostatic force
4. Force applied by muscles is called  
a) gravitational force b) magnetic force c) muscular force d) frictional force
5. The force that opposes motion is  
a) gravity b) friction c) magnetism d) muscular force
6. When a moving object slows down, it is due to  
a) balanced force b) unbalanced force c) no force d) zero motion
7. Which force pulls objects towards the Earth  
a) friction b) muscular force c) magnetic force d) gravitational force
8. A force that does not need contact is  
a) friction b) muscular force c) gravitational force d) push
9. Motion of a swinging pendulum is  
a) rectilinear motion b) circular motion c) periodic motion d) random motion
10. An object at rest will start moving when  
a) balanced force acts b) unbalanced force acts c) no force acts d) gravity stops
11. The motion of a car on a straight road is  
a) circular motion b) periodic motion c) rectilinear motion d) random motion

12. Which force helps us to walk without slipping  
a) gravity b) friction c) magnetism d) muscular force
13. The push or pull acting on an object is called  
a) motion b) force c) energy d) work
14. Motion that repeats itself after equal intervals of time is  
a) circular motion b) periodic motion c) random motion d) rectilinear motion
15. Friction increases when surfaces are  
a) smooth b) polished c) rough d) oily
16. The force applied to stop a moving bicycle is  
a) friction b) gravity c) magnetism d) muscular force
17. Which of the following is an example of circular motion?  
a) car on a straight road b) ceiling fan c) falling stone d) walking person
18. Balanced forces do NOT change the  
a) shape b) size c) direction d) state of motion
19. Which force acts between two magnets  
a) friction b) muscular force c) magnetic force d) gravitational force
20. When equal forces act in opposite directions, the forces are  
a) unbalanced b) balanced c) contact d) non-contact

## II. Fill in the Blanks 1x10=10

21. The SI unit of force is \_\_\_\_\_.
22. Friction always acts \_\_\_\_\_ the direction of motion.
23. The force required to stop a moving object depends on its \_\_\_\_\_.
24. The rate of change of velocity is called \_\_\_\_\_.
25. When an object changes its direction of motion, it is said to be in \_\_\_\_\_ motion.
26. The force that opposes motion between two surfaces in contact is called \_\_\_\_\_.
27. An object moving with constant speed in a straight line has \_\_\_\_\_ acceleration.

28. Force can change the \_\_\_\_\_ of an object.
29. Gravity is a \_\_\_\_\_ force.
30. Motion in a straight line is called \_\_\_\_\_ motion.

**III. True or False 1x10=10**

26. Force can change the shape of an object.
27. Friction helps objects to move faster.
28. Gravity is a contact force.
29. A stationary object cannot be moved by force.
30. Motion of Earth around the Sun is circular motion.
31. Balanced forces can change motion.
32. Magnetic force is a non-contact force.
33. Friction is useful in walking.
34. A moving object always remains in motion.
35. Periodic motion repeats after equal intervals of time

**IV. Match the Following 1x5=5**

Column A	Column B
36. Friction	a) Attraction by earth
37. Gravity	b) SI unit of force
38. Newton	c) Opposes motion
39. Pendulum	d) Circular motion
40. Fan	e) Periodic motion

### APPENDIX 3

#### Item Analysis

Q. No	Mean Value	Decision
Q1	0.95	Accepted
Q2	0.91	Accepted
Q3	0.86	Accepted
Q4	0.95	Accepted
Q5	0.82	Accepted
Q6	0.95	Accepted
Q7	0.82	Accepted
Q8	0.95	Accepted
Q9	0.86	Accepted
Q10	0.95	Accepted
Q11	0.95	Accepted
Q12	0.95	Accepted
Q13	0.82	Accepted
Q14	0.95	Accepted
Q15	0.86	Accepted
Q16	0.95	Accepted
Q17	0.95	Accepted
Q18	0.86	Accepted
Q19	0.95	Accepted
Q20	0.95	Accepted
Q21	0.77	Accepted
Q22	0.69	<b>Rejected</b>
Q23	0.77	Accepted

Q24	0.50	<b>Rejected</b>
Q25	0.77	Accepted
Q26	0.54	<b>Rejected</b>
Q27	0.77	Accepted
Q28	0.69	<b>Rejected</b>
Q29	0.59	<b>Rejected</b>
Q30	0.74	Accepted
Q31	0.86	Accepted
Q32	0.82	Accepted
Q33	0.95	Accepted
Q34	0.95	Accepted
Q35	0.86	Accepted
Q36	0.95	Accepted
Q37	0.82	Accepted
Q38	0.95	Accepted
Q39	0.82	Accepted
Q40	0.95	Accepted
Q41	0.86	Accepted
Q42	0.95	Accepted
Q43	0.95	Accepted
Q44	0.95	Accepted
Q45	0.82	Accepted

## APPENDIX 4

### ACHIEVEMENT TEST TOOL

CLASS: VIII

MARKS: 40

**I CHOOSE THE CORRECT ANSWER: 1x20=20**

1. A force can change the \_\_\_\_\_ of an object.  
a) colour b) shape c) smell d) taste
2. The SI unit of force is  
a) metre b) kilogram c) newton d) second
3. Which of the following is a contact force  
a) Gravity b) Magnetic force c) Friction d) Electrostatic force
4. Force applied by muscles is called  
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17. Which of the following is an example of circular motion?  
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18. Balanced forces do NOT change the  
a) shape b) size c) direction d) state of motion
19. Which force acts between two magnets  
a) friction b) muscular force c) magnetic force d) gravitational force
20. When equal forces act in opposite directions, the forces are  
a) unbalanced b) balanced c) contact d) non-contact

**II. Fill in the Blanks 1x5=5**

21. The SI unit of force is \_\_\_\_\_.
22. Friction always acts \_\_\_\_\_ the direction of motion.
23. Force can change the \_\_\_\_\_ of an object.
24. Gravity is a \_\_\_\_\_ force.
25. Motion in a straight line is called \_\_\_\_\_ motion.

**III. True or False 1x10=10**

26. Force can change the shape of an object.
27. Friction helps objects to move faster.
28. Gravity is a contact force.
29. A stationary object cannot be moved by force.
30. Motion of Earth around the Sun is circular motion.

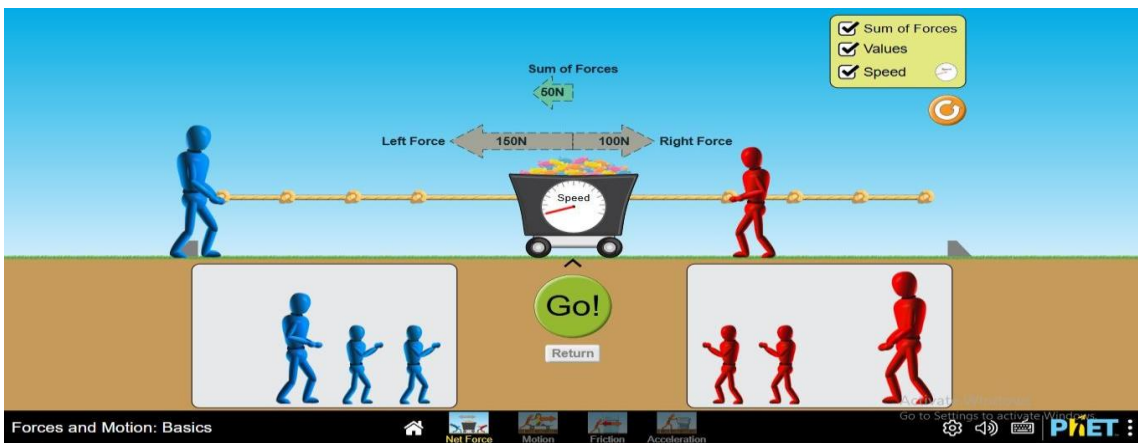
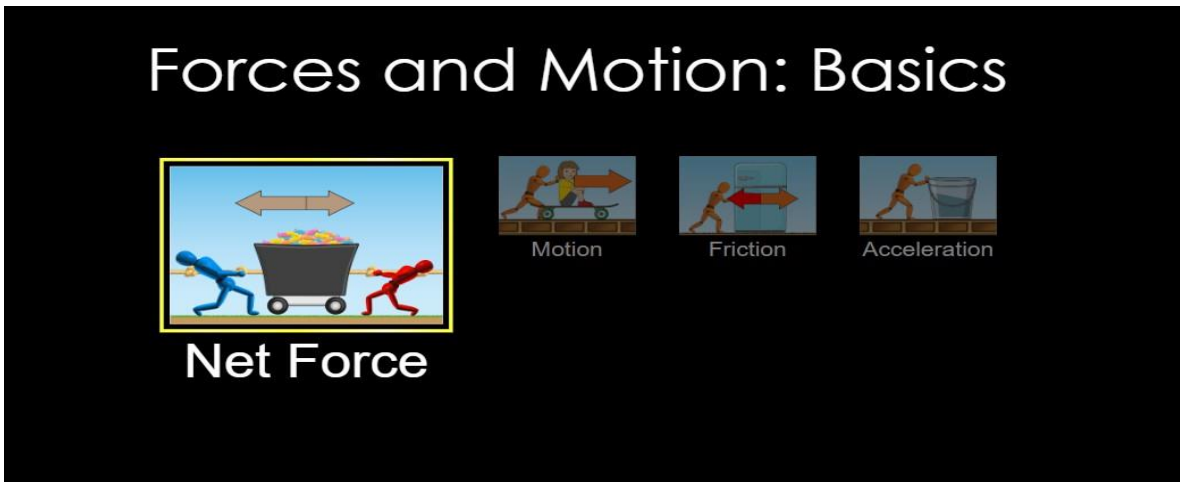
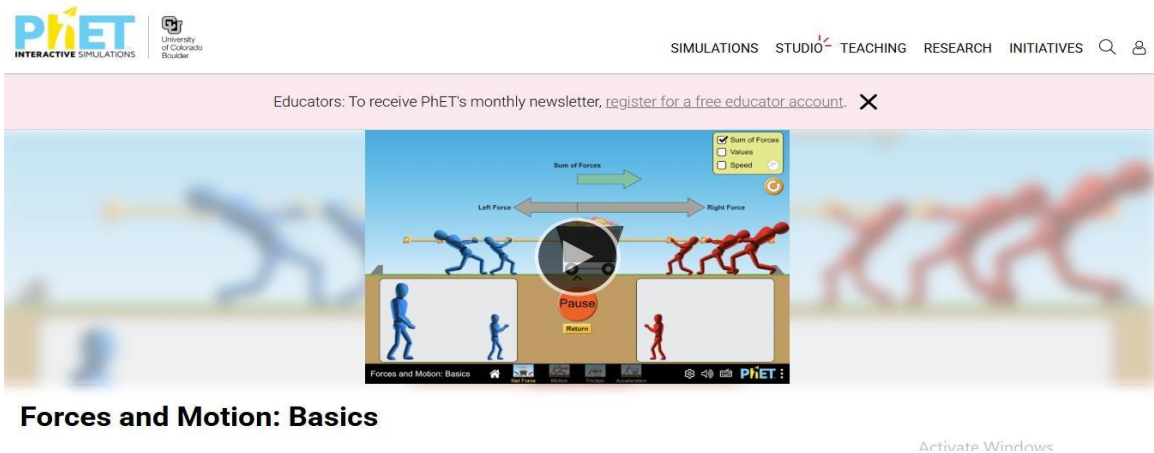
- 31. Balanced forces can change motion.
- 32. Magnetic force is a non-contact force.
- 33. Friction is useful in walking.
- 34. A moving object always remains in motion.
- 35. Periodic motion repeats after equal intervals of time.

**IV. Match the Following 1x5=5**

<b>Column A</b>	<b>Column B</b>
36. Friction	a) Attraction by earth
37. Gravity	b) SI unit of force
38. Newton	c) Opposes motion
39. Pendulum	d) Circular motion
40. Fan	e) Periodic motion

## APPENDIX 5

# EXPERIMENTAL INTERVENTION USING PhET SIMULATIONS



Speed: 8.9 m/s

00:17.50

- Force
- Values
- Masses
- Speed
- Stopwatch

80 kg

200 kg

250N Applied Force

Applied Force: 250 newtons

50 kg 50 kg

40 kg 100 kg

Forces and Motion: Basics

Speed: 0.0 m/s

00:25.47

- Forces
- Sum of Forces
- Values
- Masses
- Speed
- Stopwatch

Friction: None to Lots

Sum of Forces = 0

40 kg

50 kg

300N Friction Force

300N Applied Force

Applied Force: 300 newtons

200 kg 50 kg

80 kg 100 kg

Forces and Motion: Basics

Speed: 0.0 m/s

Acceleration: 0.00 m/s<sup>2</sup>

- Forces
- Sum of Forces
- Values
- Masses
- Speed
- Acceleration

Friction: None to Lots

Sum of Forces = 0

100 kg

80 kg

350N Friction Force

350N Applied Force

Applied Force: 350 newtons

200 kg 50 kg 50 kg

40 kg

Forces and Motion: Basics

## APPENDIX 6

### LESSON PLAN USING PhET SIMULATION

Topic: Force and Motion (Basic Concepts)

Concepts Covered: Force & Effects, Types of Forces, Friction, Balanced Forces, Units, Motion

Class: High School (VIII)

Duration: 80 Minutes

Teaching Strategy: PhET Simulation-Based Instruction

Simulation Used: Forces and Motion: Basics

#### Objectives

- Understand force as push or pull
- Learn types of forces
- Understand friction and motion

#### Teaching Aids

- Laptop & Projector
- PhET Simulation
- Worksheet

#### Previous Knowledge

- Basic idea of force and motion

#### Procedure

S.No	Stage	Time	Details
1	Introduction	10 min	Ask: Why does a ball stop rolling? Introduce force, motion, friction
2	Activity	30 min	Use simulation Students observe: • Force makes objects move • Friction slows motion
3	Explanation	20 min	Force = Push / Pull Types of forces Friction Balanced & Unbalanced forces Unit: Newton (N)
4	Practice	10 min	Worksheet: • Define force • Give examples
5	Assessment	10 min	Questions: • What is force? • What is friction? • Give one example of motion
6	Blackboard Summary	-	Force = Push / Pull Types of Forces Friction Motion Unit: Newton (N)
7	Extension	-	Find examples of force and friction at home

**APPENDIX 7**

**STUDENTS PERCEPTION OF PhET SIMULATIONS IN LEARNING  
FORCE & MOTION**

<b>Questions</b>	<b>SD</b>	<b>A</b>	<b>N</b>	<b>A</b>	<b>SA</b>
1. PhET simulations helped me understand the concept of force clearly.					
2. PhET simulations improved my understanding of motion concepts.					
3. I was able to visualize force and motion better using the simulations					
4. The simulations made abstract concepts easier to understand.					
5. I could easily observe the effect of changing variables (like force, mass, speed).					
6. PhET simulations helped me understand the relationship between force and motion.					
7. I was able to learn at my own pace using the simulations					
8. The simulations made the learning of force and motion more interesting and engaging					
9. I felt actively involved while learning through PhET simulations					
10. The simulations helped me retain concepts for a longer time.					
11. I was able to apply concepts learned through simulations to solve problems.					
12. PhET simulations helped me clear my misconceptions about force and motion.					
13. I found the simulations easy to use and operate					
14. I prefer learning force and motion through simulations rather than traditional teaching.					
15. Overall, PhET simulations enhanced my understanding of force and motion concepts.					

**SD= STRONGLY DISAGREE, A= AGREE, N=NEUTRAL, A= AGREE,**

**SA= STRONGLY AGREE**

