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The Effectiveness of PhET Interactive Simulations in Teaching Physics to Grade 7 Students: An Experimental Study

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Abstract: This study investigates the effectiveness of using PhET Interactive Simulations in teaching physics to Grade 7 students through an experimental design with experimental and control groups. Data were collected through diagnostic and final tests, classroom observations, and student questionnaires. The experimental group, taught with PhET simulations, achieved an average final score of 78 (+30% improvement), compared with 61 (+11%) in the control group taught traditionally — an improvement about 2.7 times greater. Students also showed higher motivation, engagement, and analytical thinking. The findings confirm that PhET-based instruction is an effective approach for improving physics learning outcomes at the Grade 7 level.

Keywords: PhET simulations, physics education, Grade 7 students, experimental study, academic achievement.

1. Introduction

Physics is widely regarded by learners as one of the most conceptually demanding school subjects, largely because many of its core phenomena — electric fields, wave motion, energy transfer, forces acting at a distance — cannot be directly observed with the naked eye. In traditional Grade 7 physics classrooms, these abstract phenomena are typically conveyed through lecture-based explanation, static diagrams, and textbook formulas, an approach that research has repeatedly associated with passive learning, shallow conceptual understanding, and low student motivation (Freeman et al., 2014; Prince, 2004). Teachers frequently report that limited laboratory equipment, large class sizes, and safety constraints make it difficult to provide younger adolescents with sufficient hands-on experimentation, which further widens the gap between theoretical instruction and genuine conceptual mastery.

Over the past two decades, interactive computer simulations have emerged as a practical response to this problem. Among these tools, the PhET Interactive Simulations project, developed at the University of Colorado Boulder, has become one of the most extensively researched platforms for science education (Wieman, Adams, & Perkins, 2008; Adams, Paulson, & Wieman, 2015). PhET simulations allow students to manipulate variables, observe cause-and-effect relationships in real time, and construct their own understanding of physical laws through guided exploration rather than passive reception — an approach consistent with constructivist learning theory (Bodner, 1986) and with the

broad evidence base on active learning in STEM education (Freeman et al., 2014; Prince, 2004). Prior studies have shown that PhET-based instruction can improve conceptual understanding across various physics topics and age groups (Banda & Nzabahimana, 2021; Moore, Chamberlain, Parson, & Perkins, 2014), and that well-designed simulations reduce cognitive load and support multimedia learning principles (Mayer, 2021)[1-2].

Despite this growing body of evidence, most existing studies have focused on secondary or university-level physics and chemistry courses, and comparatively little empirical work has examined how PhET simulations perform with younger, Grade 7 learners who are only beginning formal physics instruction and whose abstract reasoning skills are still developing. Furthermore, the success of technology-based instruction depends heavily on teachers' technological and pedagogical competence in integrating digital tools into lesson design (Koehler & Mishra, 2009), a factor that is rarely examined together with student outcomes in the same study. This gap motivates the present research.

Building on the theoretical foundations of interactive, simulation-based teaching discussed in a companion article, this study empirically tests whether integrating PhET Interactive Simulations into Grade 7 physics lessons improves students' academic achievement, classroom engagement, and motivation compared with traditional instruction. Specifically, the study seeks to: (1) compare final academic achievement between an experimental group taught with PhET simulations and a control group taught through traditional methods; (2) assess changes in classroom engagement, independent thinking, and inquiry skills associated with simulation-based instruction; and (3) evaluate students' and teachers' perceptions of the usefulness and practicality of PhET simulations in the physics classroom. The aim is to provide evidence-based recommendations for the wider use of PhET simulations in secondary school physics education[3-4].

2. Materials and Methods

An experimental study was conducted in three stages. In the preparatory stage, classes were divided into an experimental group (taught with PhET simulations) and a control group (traditional methods); diagnostic tests confirmed comparable initial knowledge levels, and PhET-based lesson plans were developed. In the experimental stage, the experimental group studied the same topics as the control group but through PhET simulations, with observation of understanding, independent work, inquiry skills, communication, and collaboration, alongside formative assessments. In the final stage, both groups completed final assessments, questionnaires, and interviews to compare knowledge, skills, and motivation[5-8].

Table 1. Stages of the experimental study

Stage	Activities Conducted	Purpose
Preparatory	Group selection, diagnostic testing, PhET lesson planning	Determine initial knowledge level
Experimental	Physics lessons using PhET simulations	Evaluate effectiveness of interactive teaching
Final	Final tests, questionnaires, data analysis	Assess knowledge and skill development

3. Results

Before the experiment, diagnostic testing showed comparable initial knowledge levels between groups (Table 1), providing a reliable basis for comparison.

Table 2. Diagnostic (pre-test) scores of the experimental and control groups

Group	Average score (/100)	Evaluation
Experimental	48	Average
Control	50	Average

During the experiment, the experimental group showed increased classroom engagement (+30–35%), improved independent thinking and inquiry skills (+25%), and stronger communication and teamwork. Final assessment results (Table 2) showed the experimental group's average score rose to 78 (+30%), compared with 61 (+11%) for the control group — an improvement about 2.7 times greater[9-12].

Table 3. Final test scores and improvement of the experimental and control groups

Group	Final score (/100)	Improvement (%)
Experimental	78	+30
Control	61	+11

Student questionnaires showed 85% found PhET simulations useful for understanding physics, 76% found lessons more interesting and practical, and 70% wished to continue with interactive approaches. Teachers reported that complex concepts became easier to explain, students gained confidence discussing scientific ideas, and lesson time was used more effectively for practical, student-centered activities[13-15].

4. Discussion

The results directly address the study's first objective, showing that the experimental group's final achievement (78/100, +30%) substantially exceeded that of the control group (61/100, +11%) despite near-identical starting points (48 and 50, respectively, on the diagnostic test). An improvement roughly 2.7 times greater than that of the traditionally taught group suggests that the gain is unlikely to be explained by initial ability differences alone and is more plausibly attributable to the instructional method itself. This pattern is consistent with Freeman et al.'s (2014) meta-analytic finding that active-learning approaches produce meaningfully higher achievement than lecture-based instruction across STEM disciplines, and with Prince's (2004) review concluding that active engagement with course material, rather than passive reception, is a key driver of learning gains.

The finding also converges with prior PhET-specific research. Wieman, Adams, and Perkins (2008) argued that PhET simulations succeed because they let learners see and interact with underlying physical models rather than memorizing abstract formulas, and Banda and Nzabahimana (2021) reported that PhET integration measurably strengthened conceptual understanding in physics classrooms in a different national context, suggesting the effect is not limited to a single curriculum or setting. Similarly, Moore, Chamberlain, Parson, and Perkins (2014) found that PhET-style simulations were transformative for teaching abstract scientific content in chemistry, indicating that the mechanism — visualization of otherwise invisible processes — generalizes across science subjects. The present study extends this literature by showing that the same pattern holds for Grade 7 learners, a younger age group than most prior PhET research has examined, addressing the gap identified in the Introduction.

With respect to the second objective, the increases in classroom engagement (+30–35%) and independent thinking and inquiry skills (+25%) indicate that PhET simulations

did more than raise test scores: they changed how students engaged with the learning process. This is consistent with constructivist accounts of learning (Bodner, 1986), in which manipulating variables and directly observing outcomes allows students to build their own understanding of cause-and-effect relationships rather than accepting conclusions handed to them. It is also consistent with Mayer's (2021) multimedia learning principles, which hold that well-designed interactive visualizations reduce extraneous cognitive load and free up mental resources for deeper processing of the underlying concepts — plausibly explaining why the experimental group's gains extended beyond content recall into inquiry and reasoning skills.

Regarding the third objective, the questionnaire results — 85% of students finding the simulations useful, 76% finding lessons more interesting, and 70% wanting to continue with interactive methods, together with teachers' reports of easier explanation of complex concepts and more efficient use of lesson time — suggest that the achievement gains were accompanied by, and likely reinforced by, increased motivation and more positive attitudes toward physics. This aligns with the broader finding that student engagement and educational technology are closely linked in the research literature (Bond, Buntins, Bedenlier, Zawacki-Richter, & Kerres, 2020), and underscores that the benefits of simulation-based instruction are not purely cognitive but also affective.

Theoretically, these findings support the view that PhET simulations function as a practical vehicle for constructivist, active-learning pedagogy in the physics classroom, giving Grade 7 students — who are still developing abstract reasoning skills — a concrete, manipulable representation of invisible physical processes. Practically, the results suggest that schools and teacher-training programs should treat simulation-based instruction not as a supplementary novelty but as a core methodological tool, provided teachers receive adequate training. This last point matters because the effectiveness of any technology-based method depends heavily on teachers' technological and pedagogical content knowledge and their ability to design lessons that integrate the tool meaningfully into the curriculum (Koehler & Mishra, 2009) — a factor that likely contributed to the positive outcomes observed here and that should be treated as a precondition, not an afterthought, when scaling this approach to other schools.

Several limitations should be acknowledged. The study was restricted to a single grade level (Grade 7) and a modest sample size, which limits the generalizability of the findings to other age groups, school types, and socio-educational contexts. The reliance on self-reported questionnaire data for motivation and engagement also introduces the possibility of response bias. Larger, multi-site, and longer-term studies — ideally following the same cohorts across several academic years and across different physics topics — would strengthen the evidence base and help determine whether the observed gains are durable and whether they generalize to other grade levels and subject areas, as suggested by the wider literature on educational technology and student engagement (Azevedo & Gašević, 2019; Bond et al., 2020).

5. Conclusion

Implementing PhET-based lessons in Grade 7 physics improved students' conceptual understanding and supported independent thinking, experimental skills, data analysis, and scientific reasoning, yielding an average learning-outcome improvement of about 30%. Based on these findings, it is recommended to: organize professional development seminars for physics teachers on using PhET and other digital platforms; integrate interactive technology-based methodologies into physics curricula; develop digital learning resources such as e-textbooks and simulation-based worksheets; ensure schools have adequate technological infrastructure; and introduce interdisciplinary STEAM-based approaches to strengthen digital literacy and scientific competencies.

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