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The Use of PhET Simulations in Evaluating Students' Level of Cognitive Skills Utilizing Solo Taxonomy

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Abstract
Background and Aims: Science is frequently regarded as crucial due to its links to technology and industry, which, from a national viewpoint, may be one of the areas of high priority for research, innovation and development. As digital technology emerges as a key strategy in education, this study aims to explore the effectiveness of PhET Simulations on the Grade 8 students' cognitive skills in learning essential topics in force and motion.
Methodology: The study used a mixed-methods approach, combining a quasi-experimental design with a one-group pretest-posttest for quantitative data and a sequential exploratory design for qualitative insights. The study focused on how PhET Simulations in science teaching influenced the students' cognitive skills. Qualitative data gathered through students' feedback and perceptions were analyzed using thematic analysis.
Results: Findings revealed a significant improvement in the student's cognitive skills, with a shift from a prestructural level (mean score 1.51) to a multistructural level (mean score 3.64) in the first trial and from a prestructural level (mean score 1.20) to a multistructural level (mean score 3.92) in the second trial. Statistical analysis confirmed these improvements with a significant p-value below 0.05. These results highlight the effectiveness of PhET Simulations in science education, showing that with the right tools and approaches, students can significantly advance their understanding and develop cognitive skills.
Conclusion: It was concluded that PhET Simulation is an effective tool for developing cognitive skills, thus highlighting notable progress in understanding complex concepts, increased curiosity and exploration, and boosted game-based features. While challenges such as limited access to technology, outdated versions of the gadget's OS, difficulty navigating the simulations, and the need for foundational knowledge were identified, addressing these issues could unlock the full potential of simulation, making it a highly effective tool that fosters deeper learning.
Keywords: Academic Achievement; SOLO Framework; Cognitive Skills

Introduction

The Programme for International Student Assessment (PISA) revealed that, in 2018, Filipino students ranked among the lowest in terms of academic performance in reading comprehension, mathematics, and science. According to the Department of Education (DepEd) in December 2019, these results highlighted the need for additional preparation to equip students for life beyond school. These underperformance areas were traced to specific factors, such as students' poor reading abilities, teachers' cognitive expertise, and ineffective teaching methods. This situation underscores the importance of intervention programs aimed at enhancing both teacher knowledge and pedagogy to improve student performance. The Philippines is among the lowest performing 10 out of 81 nations in reading comprehension, mathematics, and science (OECD, 2023). Despite a slight advancement in rankings, the data suggest only marginal enhancements in student performance. Specifically, there was an increase of 2.2 percentage points in mathematics proficiency from 2018 to 2022, a 6.9 percent rise in reading proficiency, and a slight decline of 0.8 percent in science proficiency (Bautista, 2023). Further analysis reveals that the SDO Division of Ozamiz City's 2023 Competency-Based Regional Achievement Test (CB-RAT) in science showed an alarmingly low Mean Percentage Score (MPS) of 47.70%, indicating significant gaps in student understanding of key learning competencies. These gaps can be attributed to various factors, including the teachers' limited cognitive expertise and teaching methods that fail to meet students' needs.

Addressing these issues is essential in improving the division's overall scientific academic performance. Because science is closely related to industry and technology, which are often viewed as

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areas with high priority for growth from a national perspective, science is generally seen as being of great importance. Studies show that the proficiency of science teachers has a significant impact on the quality of science instruction in schools and the methodologies employed. Science serves as a systematic means of comprehending the world (Assem et al., 2023).

Utilizing cognitive skills in science is crucial for individuals in a rapidly changing society. Those possessing such skills can significantly contribute to societal progress. The majority acquire these skills through formal education and engagement with their educators. Hence, teachers are responsible for enhancing the students' higher-order thinking skills (HOTS), which are essential for developing students' 21st century learning skills (Zain et al., 2022). Students exposed to innovative learning demonstrated higher average scores in higher-order thinking skills (Kwangmuang et al., 2021) and thinking critically and creatively in various ways while participating in the educational process in the classroom (Asari et al., 2019). The correlation between scientific literacy and higher-order thinking skills (HOTS) revealed that scientific literacy and HOTS encompass the understanding of scientific facts and represent advanced mental operations requiring deep information engagement (Fariyani & Kusuma, 2021). The assertion suggests that individuals with solid scientific literacy are likely to demonstrate a higher proficiency level. This implies that a solid grasp of scientific concepts facilitates critical analysis and logical reasoning and enhances problem-solving abilities (Rahman, 2019).

Conversely, honing higher-order thinking skills may contribute to a deeper comprehension and application of scientific knowledge. Thus, the proposed relationship highlights the importance of promoting scientific literacy and higher-order thinking skills within educational frameworks, as they complement each other, leading to an increased intellectual capacity and better preparation for facing complex challenges in a range of domains. Considering how teachers could create positive engagement in the classroom through technology is essential (Edwards, 2016). In the 21st century, literacy extends beyond conventional reading and writing skills; it encompasses engaging in various digital activities such as uploading, downloading, chatting, saving, sharing, and responding to content in real-time. The student generation, referred to as Generation Z, is uniquely skilled with technology in many ways. As a result, teachers need to adopt new methods and incorporate students' technology proficiency into their lessons (Hernandez-de-Menendez et al., 2020). By doing this, teachers may create a more meaningful environment for learning and teaching. Fortunately, the Internet has simplified this procedure, making the integration of technology into the classroom less intimidating and difficult for teachers.

PhET Simulations, introduced in 2002 by Nobel Laureate Carl Wieman, are an example of valuable technology that can enhance science instruction. These interactive simulations allow students to manipulate variables, observe outcomes, and explore cause-and-effect relationships in a virtual setting. PhET Simulations are especially effective in teaching abstract scientific concepts and have been shown to improve student engagement and learning outcomes (Verawati et al., 2022). Even in elementary schools, the application of PhET Simulations has been proven to positively impact students' problem-solving abilities and HOTS development (Rayan et al., 2023).

However, the challenges students face in understanding complex physics concepts, such as motion and forces, remain a significant barrier to learning. PhET Simulations can help bridge this gap by providing a more interactive and visual approach to teaching these challenging topics (Padios & Tobia, 2023). The study of motion and forces connects with other areas of physics, adding to the complexity of learning. Additionally, these ideas can often be counterintuitive—Newton's laws sometimes clash with common experiences. Real-world applications, like friction and different surface conditions, introduce further difficulties. Despite these challenges, with persistence, practice, and effective teaching, students can achieve a solid understanding of motion and forces, leading to deeper insights into the physical world. While PhET Interactive Simulations are commonly used in schools, not many studies have looked into how high school students view their usefulness for learning physics, Lin (2020). Learning more about students' opinions on how these simulations help them can guide their use in classrooms and future improvements to the simulations. Studies such as those by Cezar et al. (2024) and Luchembe & Shumba (2019) emphasize the positive impact of PhET Simulations on academic performance by improving students' understanding of key physics concepts and fostering engagement in the learning process.

Despite different assessments, students still struggle to engage with the material effectively. In this context, the use of SOLO (Structure of Observed Learning Outcome) Taxonomy, created by John Biggs and

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Kevin Collis, provides a framework for measuring the students' cognitive skills and categorizing their responses by their complexity and depth. This model goes beyond traditional grading methods, allowing educators to better understand the intricacies of student learning (Biggs, 2023). The SOLO taxonomy defines five distinct levels of learning outcomes, each representing a stage of cognitive development. These levels include Prestructural, Unstructural, Multistructural, Relational, and Extended Abstract. Starting from the most basic level, Prestructural, where students provide responses that do not address the relevant question, the model progressively advances to higher-order thinking at the Extended Abstract level, where students may use knowledge in novel situations (Caridade & Pereira, 2024).

At Marcelino C. Regis Integrated School, teachers face challenges in accurately assessing students' cognitive development in science. Despite the DepEd's guidelines on assessment, teachers remain uncertain about how to interpret assessment outcomes, particularly in science. To address this issue, there is a growing need for alternative assessment tools and strategies that provide a more comprehensive understanding of students' learning. This study proposes using PhET Simulations and the SOLO Taxonomy to assess and enhance students' cognitive skills in understanding complex science concepts such as forces and motion. By examining the effectiveness of PhET Simulations in promoting higher-order thinking skills, this study hopes to contribute valuable insights into how technology can enhance science learning outcomes and better prepare students for the challenges of the 21st century.

Objectives

This study aimed to 1) measure the students' cognitive skills in learning science with PhET Simulations using SOLO Taxonomy in both the first and second trial runs, 2) determine if there is a significant difference in students' cognitive skills before and after using PhET Simulations in both the first and second trial runs and 3) explore students' perceptions of the influence of learning science with PhET Simulations, utilizing SOLO Taxonomy, on their cognitive skills development.

Literature review

SOLO Model and PhET Simulations

The SOLO taxonomy, short for "Structure of the Observed Learning Outcome," is a framework that divides comprehension into five stages, each represented by a verb hierarchy based on cognitive complexity (Svensäter & Rohlin, 2023). The goal is to assess students' knowledge structures and understanding of topics, irrespective of the topic or domain. The challenge for teachers is to facilitate deep learning through effective teaching methods, discourage surface learning, like rote memorization, and utilize a clear framework, such as the "SOLO Taxonomy," to assess and promote students' desired levels of understanding (Biggs, 2023). Research by Agustinsa et al. (2021) indicates that students have various levels of comprehension in solving geometry problems, from basic to relational level. By using the SOLO taxonomy, teachers can evaluate students' grasp of concepts like ion formation through a structured approach. This taxonomy provides a hierarchical framework that categorizes responses, helping educators assess deeper levels of comprehension and application rather than just recall.

Numerous studies have demonstrated how successful PhET Simulations are as teaching tools. For example, Haryadi and Pujiastuti (2020) stated that the tool is interactive learning in physics and may help students become more proficient in scientific procedures. Ouahi et al. (2022) supported this, stating that using simulations aids in students' comprehension of scientific concepts effectively. Teachers can cultivate a dynamic and captivating classroom atmosphere by integrating interactive simulations, providing students with opportunities to actively explore and engage with scientific concepts in a hands-on manner. Major et al. (2021) claim that digital technology can address many educational obstacles in environments with limited resources, particularly by increasing access to educational resources and enhancing the quality of education. To make sure that digital education programs are created to satisfy the needs of students and promote successful learning outcomes, it is crucial to approach them with a thorough awareness of the difficulties and constraints. According to Antonio et al. (2023), PhET Simulations provide an effective instrument for integrating constructivist teaching methods. PhET Simulations have proven to be effective tools for promoting student learning and accomplishment when combined with constructivist instructional strategies.

Individuals' perspectives on technology can also be a hindrance. Some people may oppose change or be concerned that traditional teaching techniques may be replaced by technology. Overcoming these challenges requires investing in resources, training teachers, and changing attitudes to see technology as a helpful tool in education rather than a threat. According to Salame & Makki (2021), the use of dynamic visualization tools like PhET Simulations in the classroom can significantly enhance students' learning

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experiences by promoting active engagement, improving conceptual understanding, and fostering a deeper appreciation for science concepts can significantly enhance students' learning experiences by promoting active engagement, improving conceptual understanding, and fostering a deeper appreciation for science concepts. By implementing these strategies, educators can effectively leverage PhET Simulations to enhance student learning outcomes, promote active engagement, and deepen understanding of complex scientific concepts in the classroom. The study by Ardisa et al. (2021) revealed that PhET Simulation had a significant impact on enhancing students' critical thinking abilities in Elasticity material. This suggests that innovative teaching methods can positively impact student learning outcomes in physics education. By incorporating PhET Simulations and guided inquiry learning models into the physics curriculum, educators can make dynamic and interactive learning experiences that stimulate students' cognitive thinking skills and deepen their understanding of physics concepts.

Using the SOLO taxonomy in assessments can give teachers important insights into students' cognitive development, enabling them to customize support and intervention programs to meet individual needs. By utilizing this framework, educators aim to enhance the accuracy and validity of assessment results, thereby improving instructional practices and promoting student learning outcomes. Understanding how students learn and process information is crucial for effective teaching and creating meaningful learning experiences. Educators and researchers have developed various frameworks to analyze student responses, providing insights into the depth of their understanding. One prominent framework is the Structure of Observed Learning Outcome (SOLO) Model, which serves as a valuable tool for assessment and instructional design. Although DepEd recognized the need to support teachers in constructing valid and reliable assessments to improve the students' cognitive skills, teachers still had uncertainty about the credibility and validity of the assessment results (Dumaraos, 2022). Therefore, using assessment methods to assess and support learning is deemed necessary for teachers to employ the appropriate intervention programs to solve any issues, especially in improving the students' cognitive skills in science. Some studies, for instance (Damopolii et al., 2020), believed that using teaching strategies, such as inquiry-based learning, effectively enhanced the learners' thinking skills.

Furthermore, the study draws on educational theories such as scaffolding, which provides guidance and direction to students while they work on challenging tasks to promote learning. By examining the interplay between critical and creative thinking skills within cognitive learning and inquiry-based instruction, the study contributes to a deeper understanding of how these skills can enhance students' learning outcomes and inform instructional practices in educational settings.

Conceptual Framework

This study is anchored on Mohebi's "Unified Theory of Acceptance and Use of Technology" (2022). This model integrates various factors influencing the acceptance and use of technology, including social impact, effort and performance expectations, and enabling conditions. Technology integration, like PhET Simulations, can greatly enhance student learning, boost engagement, improve collaboration, and provide better access to resources. However, challenges such as limited funding, inadequate resources, and varying teacher skills can hinder successful integration.

This study is also anchored on the concepts of cognitive learning, critical thinking, and creative thinking of Siburian et al. (2019). Critical thinking entails assessing, analyzing, synthesizing data, and solving problems to make wise conclusions. Furthermore, the study draws on educational theories such as scaffolding, which provides guidance and direction to students while they work on challenging tasks to promote learning.

The SOLO taxonomy, short for "Structure of the Observed Learning Outcome," is a framework that divides comprehension into five stages, each represented by a verb hierarchy based on cognitive complexity (Svensäter & Rohlin, 2023). The goal is to assess students' knowledge structures and understanding of topics, irrespective of the topic or domain. The challenge for teachers is to facilitate deep learning through effective teaching methods, discourage surface learning, like rote memorization, and utilize a clear framework, such as the "SOLO Taxonomy," to assess and promote students' desired levels of understanding (Biggs, 2023). Research by Agustinsa et al. (2021) indicates that students have various levels of comprehension in solving geometry problems, from basic to relational level.

The schema of the study is displayed in Figure 1. This study involved two trials where students were assessed with a pretest before each trial, focusing on their understanding of science topics. The first trial was done during the first week of implementation, followed by the second trial in the next week. Following the pretest, students' performance in both trials was evaluated and categorized into different levels using the SOLO framework. They were then engaged in teaching sessions using PhET Simulations. After the instructional sessions, students took the posttest using the same set of questions

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in the pretest. The posttest results, displayed at the bottom of the schema, provided insight into students' science performance after exposure to the simulations.

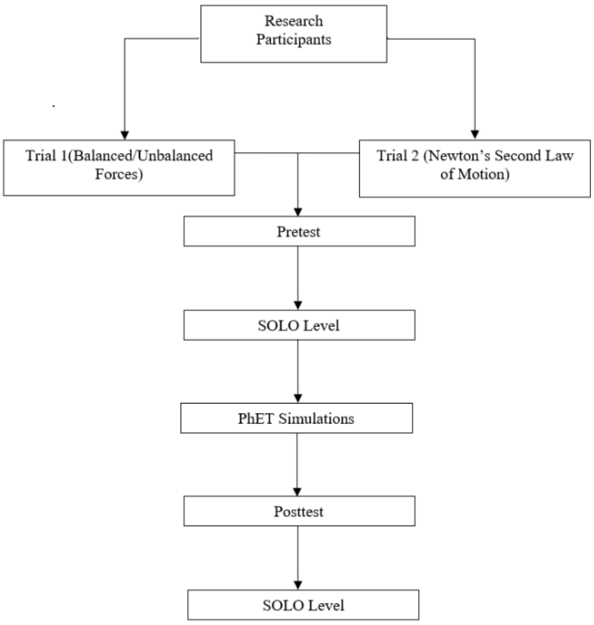

Figure 1. Conceptual Framework

Methodology

The study employed mixed methods, namely, the quasi-experimental research with one group pretest-posttest design as a quantitative measure to specify detailed answers to the research questions and sequential exploratory design to determine how students perceive the influence of learning science with PhET Simulations utilizing the SOLO Taxonomy on their cognitive skills development. With this approach, the success of the intervention was evaluated both before and after the experiment.

Figure 1 below depicts the research process in this study. The figure explains that the students will undergo two trials. The first trial focused on balanced and unbalanced forces, and the second trial focused on the Law of Acceleration. The teacher-made open-ended SOLO-based items pretest instrument was validated and tested to pass its validity. The student's level of cognitive skills during the pretest was evaluated and interpreted using the SOLO taxonomy. After the pretest in two trial runs, the teacher started the implementation. The students were taught the topics using the PhET Simulation. Immediately after the intervention, the students were given the posttest on the subjects covered during the pretest. The student's level of cognitive skills during the posttest was again evaluated and interpreted using the SOLO taxonomy.

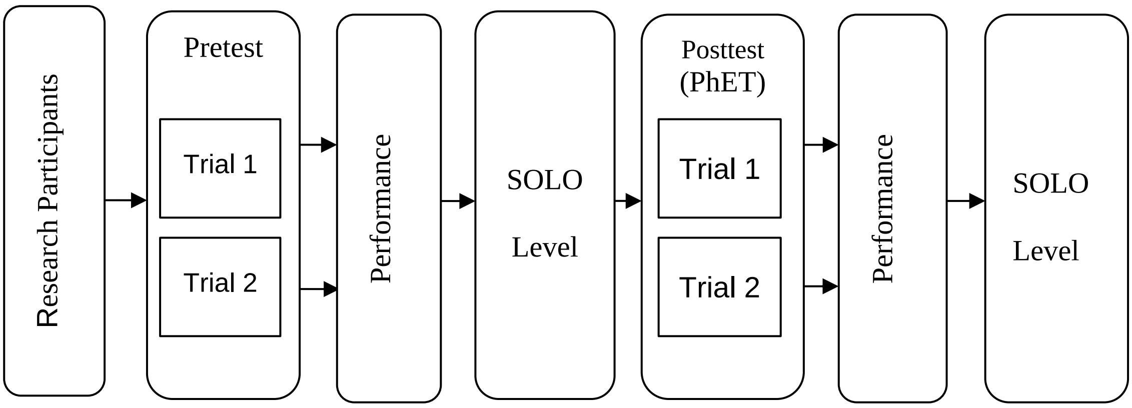

Figure 2. The Research Process

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The study used two 7E lesson plans that integrate PhET Simulations as a digital tool in teaching science. To measure the student's level of cognitive skills, the researcher employed 10 open-ended SOLO items crafted using SOLO taxonomy, which was administered before the start of the lesson and after the end of the lesson. The researcher used different science reference books to formulate the test. Experts in teaching science were asked to review, check, and validate the interview guide, the lesson plans, the 10 open-ended SOLO-based questions, the scoring rubric, and the lesson guides. After reviewing, checking, and validating, the said research instruments were endorsed to the Schools Division Office through the Education Program Supervisor in Science for internal validity and content consistency.

The study was conducted in two trial runs. In the first trial, a 10-item SOLO-based pretest on balanced and unbalanced forces was administered, followed by a discussion integrating PhET Simulations and a posttest. This process was repeated in the second trial, focusing on Newton's Second Law of Motion. Pretest and posttest scores, along with transcriptions of interview responses, served as indicators for quantitative and qualitative analyses. Data were evaluated, analyzed, and interpreted, using criterion validity to assess alignment with SOLO assessment criteria, supported by a scoring rubric, as detailed in the table below.

Table 1. Level of SOLO Taxonomy

SOLO Taxonomy	Description
Prestructural	Represents a response not addressing the relevant question
Unistructural	The focus is on a single attribute or aspect relevant to the question or activity.
Multistructural	Includes several relevant independent pieces of information or sequential actions
Relational	Integrates all relevant information or data from the stimulus. Students link the different aspects together, creating an overall coherence or pattern in their understanding.
Extended Abstract	Goes beyond what is typically expected at the relational level. Students demonstrate deeper understanding, offering deductions, connections to broader principles, and the ability to apply knowledge to new contexts.

Twenty-four students, not the subjects of this study but who had already taken the topics covered in this study, were used as a pilot sample to test the difficulty level.
The scoring procedure for the test is as follows:

SOLO Taxonomy	Equivalent Score
Prestructural	1
Unistructural	2
Multistructural	3
Relational	4
Extended Abstract	5

The interpretation of the hypothetical mean is as follows:

SOLO Level	Hypothetical Mean
Prestructural	1.00-1.99
Unistructural	2.00-2.99
Multistructural-	3.00-3.99
Relational	4.00-4.50
Extended Abstract	4.51-5.00

The data gathered in this study were analyzed using the SPSS software on a computer. This analytical tool enabled the accuracy and reliability of the computed results.

Results

Table 2 below summarizes the mean scores and corresponding SOLO levels for students' cognitive skills during a pretest in the first trial run. The data shows that all items received mean scores below 2.00, categorizing them firmly within the Prestructural level. Specifically, item 1 had the lowest

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mean score of 1.12, indicating a very limited understanding of the question. Other items, such as item 5, scored slightly higher at 1.96 but remained within the Prestructural level. The average mean score across all items was 1.51, generally under the Prestructural level, indicating that students displayed minimal comprehension of the concepts assessed. This consistent performance at the Prestructural level highlights a critical need for instructional strategies aimed at improving students' foundational understanding and facilitating their progression to higher cognitive levels. Addressing these gaps is essential for enhancing learning outcomes and fostering deeper cognitive engagement in future assessments. The finding aligns with the study by Eambaipreuk and Unyapoti (2023), which revealed that students primarily demonstrated pre-knowledge at the Prestructural level of the SOLO taxonomy during the pretest. This indicates that most students have very limited understanding and often struggle to identify key information, reflecting confusion about basic concepts.

Table 2. Students' Level of Cognitive Skills During the Pretest in the First Trial Run

Item	Prestructural		Unistructural		Multistructural		Relational		Extended Abstract		Total	Mean	SOLO Level
	N	ts	n	ts	n	ts	n	Ts	n	ts			
1	18	18	2	4	2	6	3	0	0	0	28	1.12	Prestructural
2	12	12	10	20	1	3	2	0	0	0	35	1.40	Prestructural
3	15	15	8	16	1	3	1	0	0	0	34	1.36	Prestructural
4	10	10	8	16	5	15	2	0	0	0	41	1.64	Prestructural
5	7	7	6	12	10	30	2	0	0	0	49	1.96	Prestructural
6	16	16	8	16	1	3	0	0	0	0	35	1.40	Prestructural
7	8	8	13	26	4	12	0	0	0	0	46	1.84	Prestructural
8	16	16	5	10	4	12	0	0	0	0	38	1.52	Prestructural
9	18	18	3	6	4	12	0	0	0	0	36	1.44	Prestructural
10	15	15	9	18	1	3	0	0	0	0	36	1.44	Unistructural
											Average Mean	1.51	Prestructural

Table 3 presents the students' cognitive skills during a posttest in the first trial run, utilizing PhET Simulations and evaluated using the SOLO taxonomy. The results indicate a notable improvement in students' understanding, with the majority of items scoring at the Multistructural level. The mean scores for items 1 to 10, ranging from 3.18 to 4.00, demonstrate the ability of the students to grasp multiple concepts and elements related to the content. Specifically, item 5 achieved the highest mean score of 4.00, indicating a shift to the Relational level, where students showed the ability to connect and integrate various ideas effectively. The average mean score of 3.64 confirms that students are predominantly at the Multistructural level, reflecting enhanced cognitive engagement compared to the pretest results. This improvement signifies the positive impact of using PHET Simulations in the instructional process, suggesting that such a tool can effectively facilitate deeper understanding and learning. Antonio et al. (2023) found PhET Simulations effective in integrating constructivist instruction. It is a powerful tool for facilitating student learning and achievement when integrated with constructivist teaching practices. By allowing students to actively explore and manipulate virtual tools, PhET Simulations can help students develop a deeper understanding of scientific concepts.

Table 3. Students' Level of Cognitive Skills During the Posttest in the First Trial Run

Item	Prestructural		Unistructural		Multistructural		Relational		Extended Abstract		Total	Mean	SOLO Level
	N	*ts*	*n*	*ts*	*n*	*ts*	*n*	*Ts*	*n*	*ts*			
1	2	2	3	6	9	27	11	44	0	0	79	3.59	Multistructural
2	3	3	2	4	11	33	9	36	0	0	76	3.45	Multistructural
3	1	1	1	2	13	39	10	40	0	0	82	3.73	Multistructural
4	0	0	2	4	8	24	15	60	0	0	88	4.00	Relational

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Item	Prestructural		Unistructural		Multistructural		Relational		Extended Abstract		Total	Mean	SOLO Level
	N	*ts*	*n*	*ts*	*n*	*ts*	*n*	*Ts*	*n*	*ts*			
5	2	2	0	0	10	30	13	52	0	0	84	3.82	Multistructural
6	2	2	2	4	7	21	12	48	2	10	85	3.86	Multistructural
7	0	0	4	8	12	36	9	36	0	0	80	3.64	Multistructural
8	0	0	4	8	14	42	6	24	1	5	79	3.59	Multistructural
9	1	1	4	2	13	39	7	28	0	0	70	3.18	Multistructural
10	2	2	3	6	9	27	11	44	0	0	79	3.59	Multistructural
											Average Mean	3.64	Multistructural

Table 4 illustrates the differences in student performance between the pretest and posttest during the first trial run using PhET Simulations, evaluated through the SOLO taxonomy. In the pretest, students had an average mean score of 1.51, which places them in the Prestructural level, indicating a limited understanding of the topic. The standard deviation was 0.34, showing some variation in the scores among students. On the other hand, the posttest revealed a significant improvement, with an average mean score of 3.64, placing students at the multistructural level, which signifies a deeper comprehension of the question. The posttest standard deviation was 0.35, indicating consistency in student performance. The analysis yielded a t-value of 14.34 and a p-value of 0.0001, demonstrating that the difference between the pretest and posttest scores is statistically significant. Since the p-value is well below the alpha level of 0.05, the null hypothesis (HO) was rejected, confirming that the instructional method employed positively impacts students' cognitive skills.

In the context of the Unified Theory of Acceptance and Use of Technology (UTAUT), this progress can be linked to a performance expectancy in which students' belief in the simulations' ability to improve learning outcomes is supported by the increased posttest scores, indicating that students viewed PhET Simulations as an effective learning tool. Several studies have proved the effectiveness of PhET Simulations in teaching. For example, Haryadi et al. (2020) stated that the tool is interactive learning in physics and can potentially improve students' science process skills. It was supported by Ben Ouahi et al. (2022), who stated that simulations help students understand scientific concepts effectively. Using interactive simulations, teachers can create a more dynamic and engaging learning environment that allows students to explore scientific concepts hands-on.

Table 4. Test of Difference in the Pretest and Posttest Performance of the Students During the First Trial Run

Test	AM	SOLO Level	SD	t - value	P	Decision
Pretest	1.51	Prestructural	0.34	14.34	0.0001*	Reject HO
Posttest	3.64	Multistructural	0.35			

Table 5 presents the students' cognitive skills during the pretest of the second trial run, evaluated using the SOLO taxonomy. The results indicate that many students fall within the Prestructural level, which reflects a minimal understanding of the topic. This suggests that students have limited knowledge to engage meaningfully with the items at this stage of the assessment. The mean scores for items 1 to 10 range from 0.64 to 1.96, remaining firmly within the Prestructural level. The average mean score across all items is 1.20, indicating that students are struggling to grasp the fundamental concepts being assessed. This suggests a continued need for effective instructional strategies to improve their cognitive skills and facilitate progress to higher levels of understanding in future assessments. Addressing these gaps is essential for enhancing learning outcomes and fostering deeper cognitive engagement.

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Table 5. Students' Level of Cognitive Skills During the Pretest in the Second Trial Run

Item	Prestructural		Unistructural		Multistructural		Relational		Extended Abstract		Total	Mean	SOLO Level
	n	ts	n	ts	n	ts	n	ts	n	ts			
1	15	4	6	12	0	0	0	0	0	0	16	0.64	Prestructural
2	23	23	1	2	1	3	0	0	0	0	28	1.12	Prestructural
3	21	21	1	2	3	9	0	0	0	0	32	1.28	Prestructural
4	25	25	0	0	0	0	0	0	0	0	25	1.00	Prestructural
5	24	24	1	2	0	0	0	0	0	0	26	1.04	Prestructural
6	22	22	2	4	1	3	0	0	0	0	29	1.16	Prestructural
7	20	20	1	2	9	27	0	0	0	0	49	1.96	Prestructural
8	15	15	1	2	9	27	0	0	0	0	44	1.76	Prestructural
9	25	25	0	0	0	0	0	0	0	0	25	1.00	Prestructural
10	25	25	0	0	0	0	0	0	0	0	25	1.00	Prestructural
											Average Mean	1.20	Prestructural

Table 6 showcases the students' cognitive skills during the second trial run's posttest, which utilized PHET Simulations and was evaluated using the SOLO taxonomy. The results indicate a significant improvement in students' understanding compared to the pretest. Items 1 to 4 achieved a mean score of 4.05 and 4.14, categorizing them at the Relational level. This reflects students' ability to connect and integrate various concepts effectively. Items 5 to 10 scored mean values between 3.55 and 3.91, placing them within the Multistructural level, where students demonstrate an understanding of multiple aspects but may not fully integrate them. The average mean score of 3.92 suggests that most students are now functioning at a Multistructural level, marking a substantial improvement in their cognitive skills. These changes highlight the effectiveness of using PHET Simulations as an instructional tool, which appears to have facilitated deeper comprehension of each item. These results emphasize the positive impact of innovative teaching strategies on student learning outcomes, demonstrating that with appropriate instructional methods, students can progress significantly in their understanding of complex concepts.

Furthermore, PhET Simulations provide a learning experience relating to more meaningful methods of conducting physics concepts that can be widely implemented in routine physics classroom instruction (Verawati et al., 2022).

Table 6. Students' Level of Cognitive Skills During the Posttest in the Second Trial Run

Item	Prestructural		Unistructural		Multistructural		Relational		Extended Abstract		Total	Mean	SOLO Level
	n	ts	n	ts	n	ts	n	ts	n	ts			
1	0	0	1	2	9	27	15	60	0	0	89	4.05	Relational
2	0	0	0	0	13	39	10	40	2	10	89	4.05	Relational
3	0	0	0	0	10	30	14	56	1	5	91	4.14	Relational
4	0	0	1	2	10	30	13	52	1	5	89	4.05	Relational
5	1	1	1	2	11	33	11	44	1	5	85	3.86	Relational
6	1	1	0	0	12	36	11	44	1	5	86	3.91	Multistructural
7	1	1	0	0	12	36	11	44	1	5	86	3.91	Multistructural
8	1	1	0	0	11	33	13	52	0	0	86	3.91	Multistructural
9	0	0	0	0	21	63	4	16	1	5	84	3.82	Multistructural
10	1	1	0	2	21	63	3	12	0	0	78	3.55	Multistructural
											Average Mean	3.92	Multistructural

Table 7 compares student performance between the pretest and posttest during the second trial run using PhET Simulations, evaluated through the SOLO taxonomy. The results reveal a significant

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improvement in cognitive skills. In the pretest, students achieved an average mean score of 1.20, categorizing them at the Prestructural level, which indicates a limited understanding of the topic. The standard deviation was 0.30, showing some variability in scores. In contrast, the posttest results show a substantial increase, with an average mean score of 3.92, now placing students at the Multistructural level, demonstrating a deeper comprehension of the content. The posttest standard deviation was 0.28, indicating consistent performance across the student group.

The t-value of 19.25 and the p-value of 0.0001 indicate that the difference between the pretest and posttest scores is statistically significant. Since the p-value is far below the alpha level of 0.05, the null hypothesis (HO) was rejected, confirming that the instructional methods used had a meaningful impact on students' learning. These findings highlight the effectiveness of PHET Simulations in enhancing students' cognitive skills, illustrating how engaging teaching strategies can lead to substantial improvements in understanding complex concepts. The Unified Theory of Acceptance and Use of Technology (UTAUT) supported this claim, as PhET's intuitive design reduces cognitive load, allowing students to engage with complex ideas. Furthermore, PhET Simulation-based learning delivers visuals and instructional tools that assist students in quickly understanding content knowledge, hence enhancing academic achievement and motivation levels (Banda & Nzabahimana, 2023). In addition, the result is consistent with the findings of Ndihokubwayo et al. (2020), who found that PhET Simulation effectively enhances student learning outcomes and is superior to non-PhET-based learning.

Table 7. Test of Difference in the Pretest and Posttest Performance of the Students During the Second Trial Run

Test	AM	SOLO Level	SD	t - value	P	Decision
Pretest	1.20	Prestructural	0.30	19.25	0.0001*	Reject HO
Posttest	3.92	Multistructural	0.28			

Perceptions of the Students on the Influence of Learning Science with PhET Simulations Utilizing the SOLO Taxonomy on their Cognitive Skills Development.

Three (3) emergent themes emerged in this question pertaining to the students' utilization of PhET Simulations in learning science. The themes were based on the interview transcripts and the literature and studies reviewed for the present study.

Theme 1: Enhanced Understanding of Complex Concepts. As revealed in the interview, many students agreed that PhET Simulations helped them understand lecture concepts more clearly, improved their comprehension of topics, and supported their understanding of physics concepts. Students specifically noted that the simulations enhanced their grasp of force and motion topics.

Several students noted that:

"…with PhET Simulation, I was able to clearly understand better how balanced and unbalanced forces are simulated. I want to explore more on PhET Simulations in our next topics in Science." – P3.

"Using PhET Simulations offered new learning opportunities which I believed enhanced my understanding about the topic." P5

The responses above underscore the significant impact of PhET Simulations on students' comprehension of complex scientific topics, particularly in force and motion topics. The hands-on, interactive nature of the simulations made these challenging topics more accessible and easier to grasp. These insights suggest that incorporating such simulations into the learning process can greatly enhance students' cognitive understanding and engagement with complex concepts.

Theme 2: Increased Curiosity and Exploration. PhET Simulations sparked students' curiosity and encouraged them to explore science topics further. Several students expressed an interest in learning more about different science topics available in the simulation. The interactive nature of the simulations motivated students to investigate beyond the standard curriculum, fostering a sense of inquiry and self-driven learning. This increased curiosity helped students engage more deeply in the material, making science more interesting and accessible.

One student noted that:

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"I became more curious to explore the simulation. I understand our lesson better on the concept of force and motion." - P6.

Theme 3: Game-Based Features. This explores the educational advantages of using PhET Simulations as a game-based interactive learning tool. It highlights how these simulations engage students in a fun and dynamic way, making complex scientific concepts easier to understand. By incorporating game-like elements, such as challenges and immediate feedback, PhET Simulations encourage active participation and motivation. Students often find themselves more willing to explore and experiment, which enhances their learning experience.

One student noted that:

"With PhET Simulations, it's like I'm learning while playing, just like with other apps." - P3

The game-based features of PhET Simulations provide significant educational benefits by transforming traditional learning into an engaging, interactive experience. The incorporation of game-like elements, such as challenges and real-time feedback, motivates students to actively participate and explore scientific concepts more dynamically and enjoyably. The playful yet educational nature of PhET Simulations enhances students' motivation, promotes experimentation, and ultimately enriches their learning experience.

These three themes suggest that PhET Simulations play a vital role in improving students' understanding, curiosity, and engagement in science, offering an innovative alternative to traditional learning methods. Students' feedback suggests that PhET Simulations not only supported but also enriched their learning experience by making complex scientific concepts more accessible, clear, and engaging.

Sub-question 1. What are the benefits you have acquired from learning science with PhET Simulations? This question focuses on the benefits of using PhET Simulations in learning science. It reveals how these tools positively affect the students. The discussion includes educational and motivational benefits, along with how these tools enhance student engagement and improve learning outcomes in science. Two themes emerged in this question such as increased engagement and motivation, and effective use of the simulations.

Theme 1: Students' Engagement and Motivation in Learning. PhET Simulations offer a dynamic and captivating educational encounter. Learners can interact with variables, observe results, and investigate diverse scenarios, leading to a more pleasurable and immersive learning experience. The interactive nature of these simulations effectively grabs the learner's focus and maintains their active participation throughout the learning journey. As one student shared, the simulations made it easier to understand lessons and sparked excitement to learn new topics in science. This dynamic, digital approach to learning not only captures students' attention but also promotes sustained participation, which is key to enhancing their overall learning experience.

It is noted that incorporating digital learning technology increases students' motivation for learning. Students who are motivated to study are more likely to engage in digital learning, which increases their chances of succeeding in their academic performance. PhET Simulations offer increased student engagement and motivation by providing an interactive, hands-on learning experience. The ability to manipulate variables, observe immediate results, and explore various scenarios makes learning both enjoyable and immersive. Research indicates that integrating digital learning tools like PhET Simulations can significantly boost student motivation, and motivated students are more likely to engage deeply with the material, ultimately improving their academic performance.

Theme 2: Usage of PhET Simulations in Learning Science. This theme illustrates how learners skillfully use these dynamic tools to strengthen their grasp. They discovered that the simulations' graphical and captivating quality helps them comprehend complex ideas more easily. By adjusting variables and seeing immediate outcomes, they gain hands-on experience that enriches their comprehension.

Participants revealed:

"I utilize PhET Simulations to learning activities that help and guide me through my task" – P1

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"First, I will understand the lesson efficiently by the help of my teacher. If given the chance, I will ask permission from the ICT Coordinator to use the computer laboratory room in order to use the laptops in learning the lesson with PhET Simulations" – P2

"I think it can be utilized based on the lesson presented by my teacher. I will use my gadgets to effectively use the PhET Simulation" – P3.

Students also value the self-paced nature of PhET Simulations, allowing them to revisit topics until they are already confident. This flexibility accommodates different studying styles. Furthermore, working with simulations fosters critical thinking and problem-solving as learners experiment with diverse scenarios. The opportunity to experiment with various scenarios fosters critical thinking and problem-solving skills, which are essential for deeper learning. The use of PhET Simulations enriches the learning process by providing both engaging, hands-on experiences and the flexibility to learn at one's own pace.

Sub-question 2. What challenges are encountered when learning science using PhET Simulations? How do you figure it out? This theme focuses on the challenges and issues students face when using PhET Simulations in their science learning. While many find these tools beneficial, several factors can hinder their effectiveness. Four themes emerged in this question, such as limited access to technology, difficulties in navigating the simulations, outdated versions of the gadget's operating system, and inability to master the topic due to a lack of prerequisite concepts.

Theme 1: Limited Access to Technology. Not having access to computers or reliable internet proved challenging for many students, as this limited when and where the simulations could be explored outside of classroom lessons. While the simulations provided engaging learning experiences during class time, some students were unable to grasp their understanding at home through self-directed experimentation. As several participants noted, the inability to use simulations at home restricts their opportunities for self-directed learning and experimentation, which are key to deepening their understanding. This issue highlights the digital divide that exists in some communities, where access to the technology needed for modern educational tools is not guaranteed.

Participant revealed:

"One of the problems that I have encountered is availability of learning gadgets to be used in learning" –P2

The limited access to technology presents a significant barrier to the full potential of PhET Simulations in students' learning experiences. Despite the clear educational benefits of PhET Simulations, the lack of consistent access to the necessary technology can limit students' engagement and hinder their ability to fully leverage these resources for independent learning. Addressing this gap is crucial to ensuring that all students can benefit equally from digital learning tools. While many students have expressed frustration with not being able to use PhET Simulations outside of school due to the lack of access to personal computers or reliable internet, they still try to make the most of their in-class learning opportunities. Some students, for example, take full advantage of the simulation sessions during school hours, engaging deeply with the content while they have access to the necessary technology. For those with limited access to devices, such as laptops, some students explore alternatives, like borrowing gadgets from friends or using school computers when available. As one respondent noted, the ability to use PhET Simulations is often limited to school settings, suggesting that students rely on any opportunity to access the technology during school hours.

Theme 2: Difficulties Navigating the Simulations. Some students had difficulty navigating the technical aspects of the PhET simulations, which, at times, disrupted their engagement with the instructional content.

Participants revealed:

"Without adequate guidance from my teacher, I may struggle to make the most of the simulations." –P4

"Sometimes I may find it confusing, especially since I am not familiar with the simulation. Complicated menus or unclear instructions can hinder my ability to explore and learn effectively" – P3.

The simulations contained complex interfaces with numerous tools and controls to facilitate inquiry-based exploration, but some learners struggled to intuitively operate the software without

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frustration. This posed a barrier to their independent practice with an investigation of the simulations outside of direct teacher guidance. Students encounter significant challenges when using PhET Simulations for science learning, primarily revolving around limited access to technology and difficulties in navigating the simulations. Many reported a lack of access to devices like computers and reliable internet, which restricts their ability to explore the simulations outside the classroom. This issue is particularly pronounced in communities where families may struggle to obtain the necessary technology. Without proper support from teachers, many found it difficult to fully utilize the simulations, hindering their independent practice and exploration. These challenges highlight the need for improved technology access and enhanced instructional support to optimize the use of PhET Simulations in science education.

To overcome the difficulties in navigating the PhET Simulations, students often rely on teacher guidance, peer support, and trial-and-error strategies to gain familiarity with the platform. As some participants noted, the lack of clear instructions or familiarity with the simulation can create confusion, especially when trying to understand complex menus and tools. In these cases, students often turn to their teachers for clarification. One respondent highlighted that without adequate guidance from their teacher, they struggled to make the most of the simulations. This suggests that teacher-led instruction is crucial for helping students navigate the software, especially in the early stages.

Theme 3: Outdated Version of Operating System of Gadget. Updated versions of laptops are crucial since there are instances when the PhET Simulations will not run in an outdated version of the operating system. Some lack modern devices capable of running the latest simulations smoothly. Outdated technology can lead to performance issues, reducing the effectiveness of the learning experience.

Participant revealed:

"I have an outdated laptop. The PhET Simulation is not compatible with it" –P6.

Students revealed that to ensure the successful installation of PhET Simulations, they will install the latest version of the operating system using Microsoft Office 365 provided by DepEd, which is free for each student, or ask permission from the school ICT Coordinator and School Heads to use the DepEd Computer Program (DCP) with the latest operating system pre-installed.

Theme 4: *Inability to Master the Topic Due to Lack of Prerequisite Knowledge.* Students often struggle to grasp new concepts fully when they lack the foundational knowledge required to understand them. This issue is particularly evident when complex topics are introduced, as students often rely on previous knowledge to make sense of new information. The inability to master a topic due to a lack of prerequisite knowledge presents a significant barrier to students' learning. When students lack a solid foundation in key concepts, it becomes difficult for them to understand and apply more advanced material, often leading to confusion and frustration. Some students mentioned that they initially had difficulty understanding the topic because they lacked foundational knowledge of the laws of motion. However, once they were able to use PhET Simulations, they were able to better grasp the concepts of force and motion. The key takeaway from this is that the student recognized the importance of advancing their understanding by studying foundational concepts before attempting more complex material.

Sub-question 4. What are your plans to improve your learning performance in science, considering both the benefits and challenges of using PhET Simulations? This question seeks to develop a comprehensive plan for improving the student's learning performance in science, considering both the benefits and challenges of using PhET Simulations. The main goal is to create an enriching learning environment where PhET Simulations serve as valuable tools for enhancing scientific understanding, promoting inquiry-based learning, and improving overall student performance in science subjects. This includes awareness and accessibility and developing study habits.

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Theme 1: Awareness and Accessibility. This theme highlights the importance of students' awareness of the availability of PhET Simulations and their ability to access these resources.

Participants revealed:

"I should have a background knowledge of the use of PhET Simulations in my educational gadget. I will ask assistance from my science teacher on how to use the simulations on my phone." – P3.

For some students, knowing how and where to access these simulations can significantly impact their learning experience. While PhET Simulations offer valuable educational opportunities, limited awareness and access to the necessary technology can prevent students from fully benefiting from them.

Theme 2: Develop Study Habits. This theme explores how students' study habits influence their ability to effectively use PhET Simulations and, in turn, how these simulations impact their learning strategies. Students' study habits, such as their willingness to seek additional resources, incorporate simulations into their routine, and maintain self-discipline, are crucial in maximizing the benefits of educational tools like PhET Simulations. As highlighted by Respondent 4 and Respondent 2, students who actively integrate simulations into their study routines or seek extra opportunities to engage with the technology demonstrate a commitment to deepening their understanding of science.

Two responded that:

"I will study my science lesson very hard and utilize PhET Simulation as my study routine*"* – P4

*"*I will ask permission to use the available gadgets at school to deepen my understanding on a particular topic.*"* –P2

Together, these insights suggest that enhancing student performance in science requires increased awareness, ongoing assessment and feedback, and robust technology support. By focusing on these areas, educators can foster an enriching learning environment that promotes inquiry-based learning and deepens students' understanding of scientific concepts.

Discussion

This study focused on the effectiveness of PhET Simulations in evaluating students' level of cognitive skills utilizing SOLO taxonomy among Grade 8 students of the selected public school of Ozamiz City, Misamis Occidental, for the school year 2024-2025. The study evaluated the student's level of cognitive skills in learning science with PhET Simulations utilizing SOLO Taxonomy in the pretest and posttest during the two trial runs, determined the significant differences between the pretest and posttest in the two trial runs and explored answers to this central question: How do students perceive the influence of learning science with PhET Simulations utilizing the SOLO Taxonomy on their cognitive skills development? Below is the summary of the findings:

In the first trial run, the pretest mean score for students' cognitive was 1.51, indicating a prestructural level of understanding. After using PhET Simulations, the posttest mean score rose to 3.64, reflecting a Multistructural level. This progression highlights the positive impact of using PhET Simulations in teaching, suggesting that these interactive tools can effectively foster deeper understanding and enhance learning outcomes. When the mean scores were subjected to a t-test, a significant difference existed in the students' cognitive skills in learning science with PhET Simulations, as revealed by the pretest and posttest results in the first trial run. The pretest average mean score was 1.51, indicating a Prestructural level of understanding, while the posttest average mean score increased to 3.64, placing students at the Relational level. Statistical analysis revealed a t-value of 14.34 and a p-value of 0.0001, indicating a statistically significant difference ($p < 0.05$). This supports that the instructional methods used effectively enhanced students' cognitive skills.

In the second trial run, the pretest average mean score was 1.20, indicating a prestructural level of cognitive skills. The posttest average mean score increased to 3.92, reflecting a shift to the multistructural level. This significant improvement demonstrates the effectiveness of PhET Simulations in enhancing students' understanding and engagement with the material. When the two mean scores

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were subjected to a t-test, a significant difference existed in students' cognitive skills in learning science with PhET Simulations utilizing SOLO Taxonomy, as revealed by the pretest and posttest results in the second trial run. The pretest mean score was 1.20 (Prestructural level), while the posttest mean score increased to 3.92 (Multistructural Level). The t-value was 19.25, and the p-value was 0.0001, indicating a statistically significant difference ($p < 0.05$), confirming the effectiveness of the simulations.

The central question regarding how students perceive the influence of learning science with PhET Simulations utilizing the SOLO Taxonomy on their cognitive skills development was addressed through the findings, highlighting notable progress in the understanding of complex concepts, increased curiosity and exploration, and boosted game-based features, which made learning more engaging and motivating despite initial struggles.

These findings highlight the significant contribution of PhET Simulations in enhancing students' cognitive skills in science, as evaluated using the SOLO Taxonomy framework. Such results align with prior studies (Verawati et al., 2022; Rahman, 2019) that emphasize the role of simulations in promoting conceptual learning and critical thinking and contribute new knowledge by integrating PhET Simulations and SOLO Taxonomy as a structured approach to assess and enhance students' cognitive development. The results also reinforce the findings of Kwangmuang et al. (2021), who demonstrated that interactive learning tools improve engagement and motivation, especially in science education.

Furthermore, students' positive perceptions underscore the role of simulations in simplifying abstract concepts, encouraging exploration, and sustaining interest, consistent with previous research highlighting the motivational aspects of game-based learning (Cezar et al., 2024). While challenges such as limited access to technology, outdated versions of the gadget's OS, difficulty navigating simulations, and the need for foundational knowledge were identified, addressing these issues could unlock the full potential of PhET Simulations, making it a highly effective tool for advancing science education and fostering deeper student learning.

Knowledge Contribution

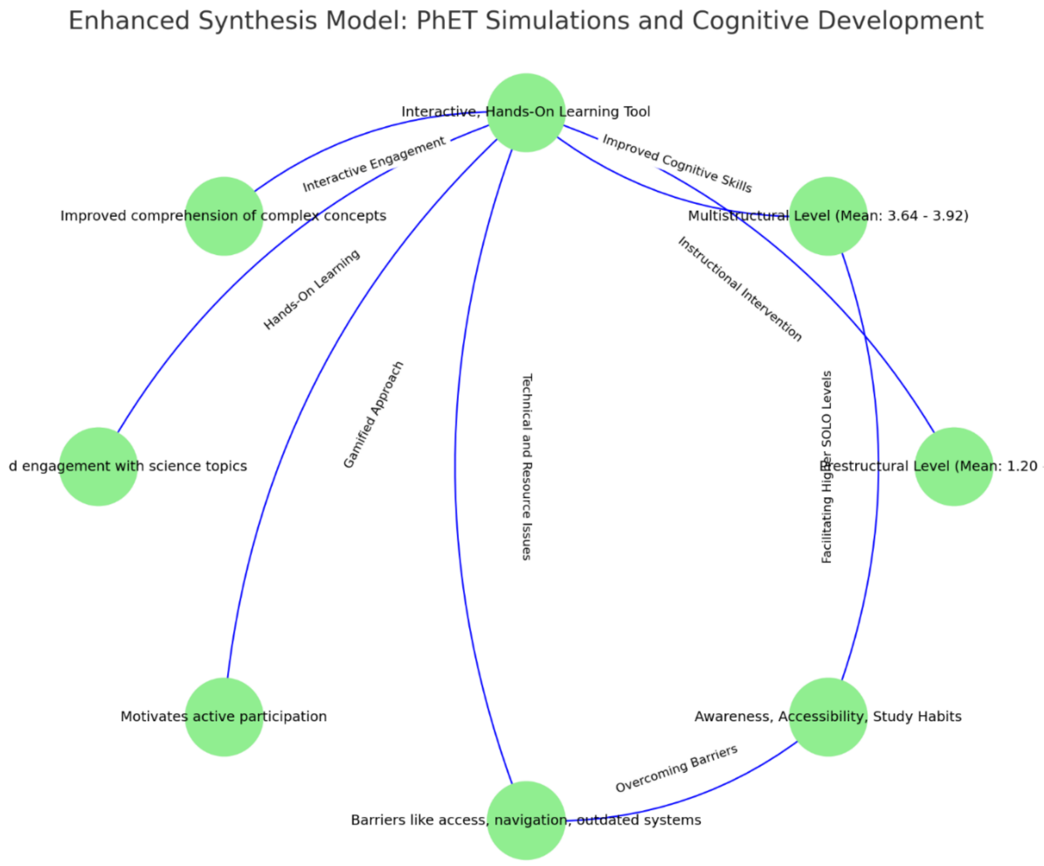

Figure 1 PhET Simulation and Cognitive Development

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The enhanced synthesis model graphically highlights how important PhET Simulations are in helping students move from the Prestructural level (pretest) to the Multistructural level (posttest) of cognitive abilities. At the center, PhET Simulations promote improved comprehension, stimulate inquiry and discovery, and offer a game-based learning environment that encourages active engagement, all of which contribute to advances in cognitive abilities. These themes are surrounded by the obstacles to advancement, such as restricted access to technology, navigational issues, and antiquated systems. Targeted tactics including raising awareness, enhancing accessibility, and creating productive study habits are used to remove these obstacles. The circular design emphasizes how these elements are interrelated and shows how PhET Simulations enhance understanding while encouraging participation and flexible learning in scientific classes.

Recommendation

It is recommended that teachers use PhET Simulations in their lessons to make learning more engaging and help students understand difficult concepts better. By using these interactive tools, students can learn in a fun and hands-on way, which can improve their learning outcomes. Teachers should also guide students in activities that encourage critical thinking and problem-solving. Future researchers should explore how PhET Simulations can be used in other subjects like mathematics, engineering, and social sciences to see if they are effective in different areas. Additionally, the SOLO Taxonomy should be used to help students develop higher-order thinking skills (HOTS), allowing them to think more deeply about the material. This can improve their understanding and help them apply their knowledge to real-world problems.

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