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USING 5E INSTRUCTIONAL MODEL WITH ICT SUPPORT IN TEACHING LOWER SECONDARY STUDENTS ON THE TOPIC OF LIGHT REFLECTION

Abstract. The educational process has become more accustomed to active classroom engagement. Physics teaching should focus more on young pupils' investigative journey. This research investigates the effect of the ICT-based 5Es instructional model on the conceptual understanding and science process skills of grade 6 pupils on light reflection. The 5E Model stands for Engage, Explore, Explain, Elaborate, and Evaluate. The study used a mixed-method design involving 24 students participating in a 5E-based intervention. The pre- and post-test results showed a significant improvement in conceptual knowledge and science process skills. Statistical analysis using paired t-tests and Cohen's d found that the 5E Model has significantly improved students' conceptual understanding of the topic and their science process skills. The study also used a phenomenological analysis and identified three critical themes that contributed to the success of the intervention. These themes were high interest and excitement in using laboratory materials, collaboration among students in exploring light reflection, and teacher scaffolding and facilitation to help students overcome challenges. The 5Es Model, which involves engaging, examining, explaining, elaborating, and evaluating stages, was highly influential in keeping students interested and enthusiastic throughout the learning process. The study confirms that the 5Es instructional model positively impacts students' science process skills and conceptual understanding. Using both quantitative and qualitative analyses provides a thorough understanding of the intervention's effectiveness and offers recommendations for improving the implementation of the 5Es Model in science education. This study recommended providing professional development opportunities for teachers to enhance their skills in implementing the 5Es instructional model. Regular workshops, collaborative sessions, and opportunities for knowledge exchange can equip teachers with up-to-date teaching strategies and insights.

Keywords: 5E model; lower secondary students; conceptual understanding of light; science process skills; hands-on learning; mixed-method design.

1. INTRODUCTION

It is incredible to think of an eager group of lower secondary school students reading about science and doing hands-on experiments while donning lab coats and magnifying glasses. Hands-on learning can lead inquiring minds through complex information terrain, transforming the process into an exciting adventure. Rather than just reading about the dance of light and reflection on a page, students can experience it through hands-on learning in physics education, which can be incredibly transformative.

The researcher observes that the light chapter has become essential for understanding higher-level physics among lower secondary school students. Specifically, reflection is a complicated phenomenon involving the interaction of surfaces and light particles. Young pupils can improve their scientific inquiry abilities and better understand the physical world by studying light and its reflected qualities. It is impossible to overestimate the influence of light's behavior, particularly about reflection, on how lower secondary school physics pupils develop their fundamental knowledge.

Encouraging young learners to learn physics can be challenging because the subject involves complex concepts. Teaching physics presents much more difficulty because the subject matter involves many intricate and complex ideas. Teachers must employ innovative teaching strategies to help pupils become more interested in science and to demystify scientific notions to overcome this obstacle [1]. Young children should find science engaging and intelligible to develop a passion for the subject and pursue further education [2].

The problem statement. Many challenges arise in teaching physics among elementary pupils. Science educators need help getting students interested in learning science. Some students may find science dull or uninteresting [3]. This scenario emerges because of a need for teaching pedagogy in some physics teachers. Getting the students into the aroma of the high-quality teaching-learning process has become a pertinent challenge in science education, even in 2023 [4]. As the world moves further in the 21st century, more natural science-related careers are needed in the industry. All science teachers should foster the spirit of experimental skills through practical work. A systematic review by Oliveira and Bonito [5] revealed that increasing students' passion for science education increases the likelihood that more students will be inspired to work in science. Because of this, the need for innovative teaching approaches is not just desirable but also essential to promoting a lifelong love of scientific research.

Incorporating innovative teaching approaches into elementary physics education is vital to address the evolving demands of the contemporary classroom and accommodate the varied learning styles of pupils [6]. The conventional one-size-fits-all method may need to be more effective at meeting the needs of developing brains. Teachers who embrace innovation can design dynamic learning spaces that meet the needs of kinesthetic, visual, auditory, and interactive learners. This action can support aspiring scientists, ignite a love of physics, and provide a solid basis for a lifetime interest in scientific inquiry.

The intervention used in this research strongly motivates the pupils by emphasizing an interactive, hands-on approach to light reflection through inquiry-based techniques in the ICT-enhanced 5E Model. It sparks curiosity, promotes a deeper comprehension of the subject, and utilizes ICT tools to establish an engaging and dynamic learning setting.

Furthermore, the ICT-enhanced 5E teaching model furnishes educators with a well-defined yet adaptable structure that promotes efficient instruction and professional growth. It provides explicit instructions for lesson organization, simplifies the inclusion of technology in the classroom, and enables ongoing evaluation and input, guaranteeing that both teaching and learning are maximized. Moreover, this Model assists teachers in honing their instructional abilities and experimenting with new teaching approaches, ultimately improving their effectiveness in conveying intricate physics concepts in an elementary education environment.

Analysis of recent studies and publications. One of these innovative teaching models is the 5E, which means engaging, exploring, explaining, elaborating, and evaluating. In this research, the 5E's were used to facilitate the topic of reflection of light among Grade 6 lower secondary students. However, using 5Es in teaching has been around for a while. For instance, Ikoh et al. [7] found that the 5E model intervention has successfully promoted conceptual understanding success among pupils in basic science. Ihejiamaizu et al. [8] said that biology students enhanced their understanding of complex topics in the stated subject. Both these studies are purely quantitative. Hence, a mixed-method study is needed to relate the quantitative and qualitative results.

Moreover, the gap in the literature lies in the limited exploration of how 5Es can develop science process skills among pupils. The meta-analysis conducted by Cakir [9] found that only five scientific articles were published on the effect of the 5Es Model on science process skills from 2005 to 2015. This revelation is seconded by a more recent systematic review of Koyunlu Ünlü and Dökme [10], which suggested that only four papers on the topic have been published in significant reputable journals since 2013. Both reviews said that most papers published were quantitative and focused more on the effect of the Model on academic achievement in science or conceptual understanding of a particular topic in biology, physics, or chemistry. In addition, the published research studies, in their reviews, were geared toward secondary and higher education students, while this ongoing research has Grade 6 pupils as participants. Therefore, a mixed-method design study is needed to explore this field further. This research also uses an ICT-enhanced 5E model, which means that during the explanation and elaboration phase of the lesson, students used PowerPoint presentation and their personally created videos to explain and discuss their experiment.

The research goal. This ongoing research investigates the effect of the ICT-enhanced 5Es instructional model on the conceptual understanding and science process skills of grade 6 pupils on light reflection. This research intends to answer the following questions: 1) Can the ICT-enhanced 5Es instructional model improve the conceptual understanding of the Grade 6 pupils in light reflection? 2) Will the Grade 6 students have improved science process skills after using the ICT-enhanced 5Es instructional model? 3) What are the Grade 6 pupils' perspectives and experiences as they were immersed in the intervention?

2. THE THEORETICAL BACKGROUNDS

This study is rooted in the 5E Instructional Model. The 5E Instructional Model, developed by the Biological Sciences Curriculum Study (BSCS), facilitates active learning and more profound understanding through a structured approach. It comprises five phases: Engage, Explore, Explain, Elaborate, and Evaluate, each aiming to progressively build on the previous one, creating a cohesive learning experience. The Engage phase seeks to pique students' interest and stimulate their curiosity by linking the lesson to their prior knowledge and experiences. This phase often involves posing thought-provoking questions, presenting surprising demonstrations, or introducing relevant problems to encourage critical thinking and prepare students for the upcoming learning material. The Engage phase sets the groundwork for meaningful learning by establishing context and relevance.

This ongoing research is also anchored on the constructivist learning theory. This theory clarifies how knowledge is created inside an individual due to interactions between newly acquired knowledge and previously developed knowledge modified by experiences [7]. The constructivist theory offers a contemporary approach to education based on a conceptual framework that views the teacher as a guide, facilitator, and architect of the learning environment [8]. Constructivist philosophy is incorporated into the 5Es Model by emphasizing experiential learning, inquiry-based learning, and the iterative process of explanation and exploration. This Model gives teachers a well-organized framework to support constructivist ideas at every learning process step. It also encourages students to participate actively and helps them build knowledge through first-hand experiences.

3. RESEARCH METHODS

3.1. Research Design

This research followed the sequential explanatory mixed-method design. A sequential explanatory mixed-methods approach involves the collection and analysis of quantitative data initially, and the final stage entails gathering qualitative data [11]. This method allows the researcher to comprehend, clarify, or analyze the quantitative results more deeply [12].

The main objective of the quantitative phase of this present study is to assess the 5E instructional Model's effects on elementary pupils' conceptual knowledge and science process skills quantitatively, with a particular emphasis on light reflection. The quantitative phase followed the quasi-experimental design with pre-test and post-test. To do this, pupil participants explored the light reflection using the 5E Model with the facilitation of an expert teacher. A pre-test was administered to the pupils to determine baseline levels of conceptual comprehension and science process skills. After the invention, post-tests on the same tests were given so that the efficacy of the intervention could be determined.

The research proceeded from a quantitative phase to a qualitative investigation to provide a more comprehensive knowledge of the experiences of elementary school pupils exposed to the 5E Instructional Model. To learn about their perspectives and experiences throughout the educational intervention, pupils answered a reflection form, and a focus group discussion was held during the plenary and reflection phase of the lesson. Furthermore, classroom observations were made to provide the qualitative results with more context.

3.2. Research Participants

A total of 24 pupils joined this lesson and experiment. Since all of them are already in intact classes, no control group follows the principle of Education for All. If a control group were given traditional lessons, it would be unfair to this group because they would not experience the same high-quality teaching and learning. Moreover, there is no selection bias because students were already in intact groups, and the vice principal grouped them based on a competitive examination.

The experiment was conducted at the Presidential School in Qarshi. All 24 participants have similar characteristics because they were selected for the said school based on a very competitive Cambridge Assessment International Education (CAIE) examination. All 24 pupils were involved in both phases of the research design.

Before the experiment, a letter of informed consent was given to the parents of these pupils, and all parents signed the document. Also, a letter of approval was sent to the school principal to conduct this experiment. All parties were informed that all information was only for research purposes and that their children would not be harmed.

3.3. Data Collection Tools

The researcher prepared two research instruments. These were the Test on Conceptual Understanding of Reflection of Light and the Test of Science Process Skills. Both of these tests were developed based on the learning objectives of the CAIE lower secondary syllabus for stage 8 level under the chapter on Light Properties. The conceptual understanding test was also based on Bloom's taxonomy of learning objectives, and the science process skills test was based on the reflection of the light experiment. The use of these two instruments is aligned with the research objectives, which means the objectives are better answered using the two instruments.

The researcher made a total of 30 multiple choices for each of the tests. These instruments were sent to two science teachers and one instrument professor for face validity and content validity. These experts have at least five years of classroom assessment tool-making experience and have been members of the panel scrutinizing teacher-made tests. The validators utilized Waltz and Bausell's [13] content validity rating scale to validate the contents. Based on their validation, five questions in the science process skills test were removed, and eight questions were eradicated in the conceptual understanding test.

Moreover, the instruments were fielded to the higher-grade-level students in the same school for internal consistency analysis. It was revealed that the internal consistency, using Cronbach's Alpha, of the Test on Conceptual Understanding of Reflection of Light was 0.71, and that of the Test of Science Process Skills was 0.74. These alpha values are relatively high in reliability, as Taber [14] described.

The final count of questions was 25 for the conceptual understanding test and 13 for the science process skills test. The abstract understanding test contained four remembering questions, six understanding questions, five applying questions, five analysis questions, and five evaluating questions. The questions in the Test on Conceptual Understanding of Reflection of Light can show the student's mental and physical processes during the experiment. For instance, a question asks students to forecast the path of reflected light, and the students have to use their visualization prowess to answer the question correctly. The test on science process skills comprised two classifying questions, three controlling variable questions, three inferring questions, two hypothesizing questions, and three interpreting questions. The questions were categorized according to their difficulty using Bloom's taxonomy of cognitive processes.

3.4. Research Framework and Data Collection Procedure

The total study period was five days. During this study period, they followed the framework of the ICT-enhanced 5Es instructional model. As already said, the 5Es encompass engaging, exploring, explaining, elaborating, and evaluating. The timeline and activities are presented in Table 1.

On day 1, the pupils answered the Test on Conceptual Understanding of Reflection of Light and the Test of Science Process Skills as a pre-test. Before the test started, the teacher read the instructions to the students, which is also stipulated on the paper. The pupils were given 30 minutes to finish the test, which started at 8:00 in the morning and ended at 8:30 am. During the test, pupils were seated half a meter apart to avoid cheating. Also, clippings and posters that contained references for the test were removed from the walls. There was also good ventilation in the classroom.

The engaging phase started on day one by allowing students to look at their images in a mirror with a smooth surface and from a glass with a rough surface. Students explored the difference in the image produced and explained how it happened. A 3-minute video about light reflection was also shown to the students, and the processing of this video through analysis questions followed. The Socratic method was used during the analysis of the footage presented, in which students were randomly called to answer the questions.

Table 1

The timeline and activities during the entire lesson

5E Model Phase	Day	Student Activities
Engaging	1	● Looking at the image projected on the mirror ● 3-minute video presentation
Exploring	2	● Experiment proper ● Collection of experiment pictures and videos
Explaining	3	● PPT and video presentation
Elaborating	3	● Discussion and analysis
Evaluating	4	● Assessment (Post-Test)

The hands-on experiment happened on day 2. The materials needed for the experiment were a mirror, protractor, ray box with battery, and pencil. Figure 1 shows how pupils experimented. At this stage, the teacher facilitated while the researcher observed the pupils. The pupils explored first by flashing the light from the ray box at one angle and measuring its corresponding angle of reflection. They noticed the angles were the same and explained that the law reflection was correct.

The experiment lasted 25 minutes until the students collected six angles of incidence and six angles of reflection. They were told to take pictures of their experiments so that they could add them to their presentation during the explanation and elaboration phase. Then, the pupils drew the line graph and interpreted it.

On the third day, a plenary was held to ask students about their observations, inferences, interpretations, and conclusions. There was a group presentation of what transpired during their experiments. Three groups used PowerPoint presentations, and one made a video to discuss the experiment. The presentation also included the sources of error they got and improvements they would make in future experiments.

On the fourth day, the students answered the Test on Conceptual Understanding of Reflection of Light and the Test of Science Process Skills again, this time as a post-test. These tests also served as the assessment tool. Similar test regulations were followed during the post-test. The students had half an hour to complete the test, which took place from 8:00 to 8:30 am. To prevent cheating, they were seated with a distance of 0.5 meters between them, and any materials on the walls that could be used for reference were removed. Additionally, the classroom had proper ventilation.

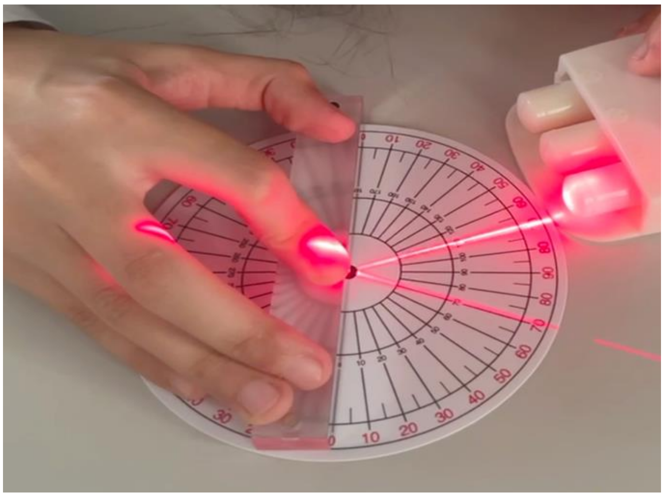

Figure 1. Students proved the law of reflection by conducting a hands-on experiment.

On the final day, pupils answered the interview questions using Google Forms. The questions were: What did you find interesting or exciting about the experiment with the mirrors and light? Can you describe what you did with the mirrors and light during the experiment? What challenges did you face, and how did you overcome them? The pupils answered in English, and all of the 24 pupils responded.

4. THE RESULTS AND DISCUSSION

4.1. Quantitative Results

The pupil's conceptual understanding and science process skills scores were categorized based on the Cambridge Assessment International Education scoring scale because the school uses the said international program as its curriculum. These categorizations are shown in Table 2 and Table 3.

A wide range of student grades are represented in the pre-test results, with a noteworthy 29% of students falling into the C group (60–69). The post-test results, however, show a significant change, with 0% of pupils falling into the C category. This data shows a positive trend, meaning that students originally graded in the C category have improved their performance on average and moved up to higher grade levels. At the same time, there are notable gains in the A* and A categories, with percentages going from 17% to 79% and 29% to 13%, respectively. The drop in the B category from 25% to 8% means that students improved to a higher grade scale. Overall trends point to a good and optimistic trajectory, with most pupils advancing towards higher success levels regarding their science process skills.

Table 2

The distribution of scores in science process skills

Grade Scale	Pre-test	%	Post-Test	%	Mean difference (95% CI)
A* (90 – 100)	4	17	19	79	15
A (80 – 89)	7	29	3	13	6
B (70 – 79)	6	25	2	8	-4
C (60 – 69)	7	29	0	0	-7
D (50 – 59)	0	0	0	0	0
E (40 – 49)	0	0	0	0	0

Only some students could answer questions on controlling the variables and interpreting data in the pre-test. They mostly scored low on low-level questions such as classifying. However, the scores increased in controlling variables, inferring, hypothesizing, and interpreting questions after the intervention.

Table 3

The distribution of scores in conceptual understanding of reflection of light

Grade Scale	Pre-test	%	Post-Test	%	Mean difference (95% CI)
A* (90 – 100)	0	0	14	58	14
A (80 – 89)	5	21	7	29	2
B (70 – 79)	8	33	3	13	-5
C (60 – 69)	9	38	0	0	-9
D (50 – 59)	2	8	0	0	-2
E (40 – 49)	0	0	0	0	0

Table 3 shows that a sizable fraction of pupils was spread across many grade levels in the pre-test, with the C category (60–69) having the largest share at 38%. The post-test findings, however, show a noticeable shift in the student's performance. The A* category demonstrates a notable improvement, going from 0% in the pre-test to 58% in the post-test. Positive development is also seen in the A category, where the percentage increased from 21% to 29%. The percentage of students in the B group drops from 33% to 13% because they move to a higher grade scale. The overall trend points to improvements in student success in their conception of the reflection of light. The mean differences corroborate the results, which indicate a noteworthy improvement in scores. Specifically, the A* category demonstrates a substantial mean difference of 14 (95% CI: 0 to 28).

The data in Table 4 shows the scores of 24 participants on a pre-test and a post-test regarding Conceptual Understanding and Science Process Skills. The average pre-test score for Conceptual Understanding was 17.8 out of 25 (with a standard deviation of 2.26). In contrast, the average score in the post-test increased significantly to 22.6 (with a standard deviation of 1.93). This data indicates a substantial improvement in the participants' conceptual understanding. The standard deviation of both pre-test and post-test scores suggests that the participants performed consistently throughout the tests. The post-test mean score was closer to the maximum score, implying that the intervention improved participants' understanding.

Table 4

Descriptive statistics for pupil’s scores on the two tests

Test	N	Pre-test Mean	SD	Post-Test Mean	SD
Conceptual Understanding	24	17.8	2.26	22.6	1.93

Science Process Skills	24	10.3	1.09	12.1	0.947

Similar to the results of the science process skills, pupils score low on higher-order questions such as evaluation, analysis, and application on the pre-test. The intervention improved the scores in higher-order and low-order thinking questions after the intervention. Most students scored A* (90-100) and A (80 – 89), meaning that most students were at a higher thinking level in Bloom's Taxonomy.

The table also shows the pre-test and post-test scores of 24 participants in Science Process Skills. The average pre-test score was 10.3 out of 13 (with a standard deviation of 1.09), while the post-test mean score rose to 12.1 (with a standard deviation of 0.947), indicating substantial progress in these skills. The standard deviation of both pre-test and post-test scores suggests a more homogeneous improvement in science process skills across the participant group. The post-test mean score was closer to the maximum achievable score, indicating that the intervention successfully enhanced participants' proficiency in science process skills. Overall, the intervention successfully improved both Conceptual Understanding and Science Process Skills among the participants, as evidenced by the significant increase in mean scores and the consistent improvement across the group.

According to the Shapiro-Wilk test for normality, the results show that the Conceptual Understanding and Science Process Skills data are normally distributed. Although the p-values are slightly higher than the standard threshold of 0.05, there is no significant evidence to reject the null hypothesis that the data follows a normal distribution. These findings suggest that the pre-test and post-test scores for Conceptual Understanding and Science Process Skills are reasonably consistent with normal distribution. These findings only signified that using a paired t-test is reasonable for this study.

Table 5

Test of normality result using Shapiro-Wilk

Test	W	p-value
Conceptual Understanding	0.916	0.058
Science Process Skills	0.921	0.062

The statistical analysis of the pre-test and post-test results for Conceptual Understanding yielded some impressive findings, as presented in Table 6. Using a paired t-test, the p-value is computed at <0.001, less than the 0.05 significance level, indicating a significant difference between the pre-test and post-test scores. The paired t-test in Table 6 showed a significant improvement, with a large effect size (Cohen's d = 1.60), indicating that the intervention had a practical and meaningful impact on the participants' understanding. The mean difference of 4.750 and a tight confidence interval (95% CI = 3.487 to 6.003) further highlighted the robustness of these results and the unlikely possibility of it being due to chance. The study suggests that the participants' Conceptual Understanding has significantly improved after the intervention.

Table 6

The outcomes of a paired sample t-test and Cohen's d for conceptual understanding and science process skills

Variable	t	df	p	Mean Difference	S.E. Difference	95% CI for Mean Difference		Cohen's d
						Lower	Upper	
Conceptual Understanding	7.842	23	<0.001	4.750	0.606	3.487	6.003	1.60
Science Process Skills	7.224	23	<0.001	1.792	0.248	1.279	2.305	1.48

The paired t-test also produced a very significant result (t = 7.224, df = 23, p < 0.001) in Science Process Skills, demonstrating a notable improvement from the pre-test to the post-test. With <0.001 p-value, this is lower than the 0.05 significance level, which means there is a significant difference in pre-test and post-test scores. As measured by Cohen's d, the effect size is 1.48, suggesting that the intervention had a strong and practically meaningful impact on Science Process Skills. With a standard error of 0.248 and a mean difference of 1.792, the results indicate a significant improvement in the participants' scores. The consistency of this improvement is demonstrated by the 95% confidence interval (CI) for the mean difference, which spans 1.279 to 2.305. These results show that, both statistically and practically, the intervention has improved participants' competency in science process abilities, indicating that it has been successful in helping participants develop a more sophisticated skill set.

4.2. Qualitative Results

Three main themes emerged from the phenomenological analysis of the qualitative data. These are high interest and excitement in using laboratory materials, collaborating in exploring the reflection of light and overcoming challenges with the experiment. The combination of high interest, collaboration, and the ability to overcome challenges contributed to a positive and enriching learning environment throughout the experiment.

The participants' positive and enthusiastic response towards the hands-on experience of using different laboratory materials during the light reflection experiment was evident in their high interest and excitement, indicating a strong interest in the experimental process. The pupils used positive descriptors like “fun,” “great,” and “love it,” which embodied their perspective from the experiment. They were fascinated with the equipment used. The excitement experienced by students in laboratory settings can be attributed to the novelty of using laboratory materials. The sense of wonder and curiosity sparked by discovering the behavior of light, understanding the law of reflection, and observing reflections in experiments using specific materials all contribute to this excitement. The following are note-worthy statements coming from the pupils.

“I observed that the law of reflection performed as anticipated. I utilized a protractor to measure both the incidence and reflection angles. The light emanating from the ray box caught my attention and proved exceptionally captivating." – Kent.

“I am intrigued by the reflection of light. I am thrilled that you provided us with a laser. I am interested in measuring angles.” – Margaret.

The qualitative data provided by the students indicates that the theme of collaboration in exploring the reflection of light is a prominent and recurring aspect. The students' statements consistently emphasize the benefits of working together and the shared experience of exploring the reflection of light. Pupils narrated their enhanced learning through teamwork during the experiment. Students perceive collaborative efforts as improving the learning experience. They mention that working together makes the experience enjoyable and contributes to a more profound understanding of concepts related to the reflection of light. The theme implies that collaboration among pupils leads to a sense of mutual excitement. The shared exploration of light reflection becomes a collective source of interest and engagement, magnifying the positive feelings associated with the experiment. The following are significant statements from the pupils that supported this theme.

“I enjoy collaborating with a partner, and we worked in pairs during the experiment. I also have an affinity for measurements, and we created a table related to this subject.”- Ivan.

"There were many aspects that I found appealing. Additionally, I have a preference for activities or experiments conducted in pairs. The experiment was awe-inspiring." – Jacob.

“Because my partner and I worked well together, I had no problems. I enjoyed experimenting, and our systematic approach paid off.”- Strauss.

The third theme talks about overcoming challenges during the experiment. Many pupils faced numerous challenges. Some had trouble using a protractor, directing lasers accurately, or placing the mirror correctly. Despite these difficulties, the students demonstrated resilience and a problem-solving attitude. They sought help from teachers, collaborated with peers, and made repeated attempts at the experiment until they got it right. One notable example is how a student asks the teacher if his analogy is correct by comparing the light's reflection with the ball's bouncing. This example only shows how students’ mental activities ran during the session.

The students realized the crucial role of accuracy in measuring angles in the scientific process. This theme highlights the participants' determination to overcome obstacles and succeed in the experiment. The following are prominent statements from the participants that support this theme.

“Drawing lines of reflection and incidence was challenging because the mirror kept moving.” – Anton.

“I focused on aligning the lasers with the normal line, putting in extra effort to avoid accidental mirror movement. Additionally, I became more attentive towards this aspect. I assigned this task to my teammate to measure the angles accurately."- Van.

“To fix the issue with the ray of light, we decided to use the lights on the opposite side due to the complexity of the task. Working with the window presented a few difficulties, but we collaborated to overcome them and ultimately achieved success.” – Francia.

4.3. Discussion

Based on the findings, the 5Es instructional model's intervention increased the students' scores in conceptual understanding of light reflection and science process skills. Many students moved up the grade scale, most at the A* (90-100) level. The mean scores also increased, with standard deviation data revealing good reliability.

When subjected to the statistical analysis of paired t-tests, the scores calculated a p-value below the 5% significance level, which means that there is a significant difference between the pre-test and post-test scores in both tests. Cohen's d findings highlighted a substantial increase in the scores. The findings showed that students grasped the gist of the lesson using the 5E Model, and their science process skills were increased or developed. This result agreed with the findings of Ikoh et al. [7], which found vast differences in post-test and pre-test scores regarding students' academic performance using 5Es. They concluded that the constructivist instructional strategy known as the 5Es appears to be successful in improving students' capacity to articulate scientific concepts. Sotakova and Ganajova's [15] study found similar results. It argued that the 5E Model introduces students to challenging scenarios, encourages active thinking, and offers opportunities to investigate, elucidate, expand, and assess their understanding. The teacher observed that when pupils study the reflection of light, they frequently imagine how light beams reflect off a surface. This entails mentally visualizing the incoming angle of light and the outgoing angle of reflection. Also, students may form mental representations to comprehend how light acts when it hits various surfaces, like mirrors or uneven surfaces.

Moreover, this research claims that there is a gap in this research, as there are few studies about the impact of the 5Es Model on the students' science process skills as examined by a meta-analyses review conducted by Cakir [9] and Koyunlu Ünlü and Dökme [10]. In this research, the 5Es models enhanced students' skills in observing, classifying, controlling variables, inferring, hypothesizing, and interpreting. The pupils excelled in all of these parameters. The study of Cheng et al. [16] revealed similar findings: students who showed 5E instruction had higher science process skills than those who did not.

The qualitative findings explained the emergence of higher scores in conceptual understanding and flying high science process skills. The phenomenological analysis revealed three critical points for this success. These are high interest and excitement in using laboratory materials, collaboration in exploring the reflection of light, and overcoming challenges with the experiment through teacher scaffolding and facilitation strategy and repeated attempts to find the answer to the experiments. The 5Es Model was highly engaging and followed constructivist principles in teaching and learning. The engaging and exploration stage is highly interesting and exciting for the pupils of this research. Without this bait, the pupils may not lose momentum, which can ultimately affect their knowledge conception and process skills. Walan [17] argued that lesson starters are essential to ignite the attention and hook them throughout the lesson. This is what happened in the lesson in this research; students were on board with the lesson from day one to the final day.

In addition, the students collaborated during the experiments. They were paired into two. They stated that they devised a plan for experimenting, which worked for their group. Another vital revelation in this study is that students grouped during 5Es have successful conception and science process skills. Manishimwe et al. [18] argued that group activities using 5Es heightened students' enthusiasm for biology, enabling students to understand the practical applications of biology in real-life situations, leading to a positive shift in their attitude towards the subject. Engagement also increased during grouped work in 5Es, as revealed by Garcia et al. [19]. This explains David Kolb's experiential learning theory.

It was obvious that during experiments, pupils encountered issues, especially grade 6 pupils who were just new to the study of science. The teacher was crucial in guiding and supporting the pupils during the experiment. This process was done through scaffolding and facilitation, where participants sought help and advice from their teachers. For instance, some pupils faced challenges such as using a protractor, directing lasers accurately, or understanding certain aspects of the experiment. This highlights the significance of educators in assisting students in navigating through experimental difficulties. During the lesson, a student sought clarification from the teacher by questioning the accuracy of his analogy, which compared the reflection of light to the bouncing of a ball. This incident illustrates the cognitive processes of the students during the class.

The participants found repeated attempts to be a valuable strategy for overcoming difficulties during the experiment. This was evident when participants encountered challenges such as measuring angles or placing the mirror in the correct position. Through multiple attempts, they learned from their mistakes, refined their techniques, and ultimately found solutions to the experiment's complexities. The emphasis on persistence and the repeated nature of the scientific method highlight the significance of engaging in hands-on learning.

4. CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

Implementing the ICT-enhanced 5Es instructional model has proven highly effective in improving students' understanding of light reflection and their science process skills. The data analysis showed a significant score increase, with many pupils advancing to higher grade levels, especially in the A* category. The statistical findings and Cohen's d further confirmed the 5Es Model's substantial impact on students' academic performance. These results align with previous studies that demonstrate the success of the constructivist instructional strategy in improving students' ability to explain scientific concepts. Most students improved their scores on the higher thinking questions, such as evaluating, analyzing, and applying the topic after the intervention. This research is unique in that it emphasizes the positive influence of the 5Es Model on science process skills, addressing a gap identified in prior meta-analysis reviews. Science process skills, such as controlling variables and interpreting the data, improved, which was low before the ICT-enhanced 5Es instructional model intervention. The teacher-made instrument, which is valid and reliable, was highly successful in measuring the different constructs under study.

The qualitative findings revealed the critical success themes, including high interest, collaboration, and practical teacher support, which helped to overcome challenges during experiments. The 5Es Model is engaging and explorative, and its emphasis on collaborative group work contributed to sustained student interest and enthusiasm throughout the learning process. These qualitative results explained the emergence of increased conceptual understanding and science process skills of the students. Thus, the mixed method was successful in its goal to explain the quantitative results through the qualitative data.

Moreover, mental processes like visualization, logical reasoning, and analogy were evident among students. These cognitive processes helped them solve the two instruments with outstanding results. This only means that by combining the mental activities mentioned, collaborative lessons and engaging lessons collectively contributed to the pupils' success in this experiment.

It is essential to highlight the significance of providing ongoing professional development opportunities for teachers to enhance their skills in implementing the 5Es instructional model. Regular workshops, collaborative sessions, and opportunities for knowledge exchange can equip teachers with up-to-date teaching strategies and insights. This investment in teacher development aligns with the constantly evolving nature of education and guarantees that educators remain proficient in successfully utilizing the 5Es Model in the classroom.

Creating robust strategies that align with the 5E Model is crucial for assessment. Assessments should gauge students' understanding of concepts and evaluate the progress of their science process skills. A blend of formative and summative assessments, including project-based evaluations, will comprehensively understand students' learning outcomes. Also, a new frontier could be how the 5E model could be maximized in a fully online learning environment or in alternative learning systems.

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ВИКОРИСТАННЯ НАВЧАЛЬНОЇ МОДЕЛІ 5E З ІКТ ПІДТРИМКОЮ ПІД ЧАС ВИВЧЕННЯ УЧНЯМИ ЗАГАЛЬНОЇ СЕРЕДНЬОЇ ОСВІТИ ТЕМИ ВІДБИТТЯ СВІТЛА

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Анотація. Освітній процес сьогодні базується на активній роботі в класі. Викладання фізики повинно більше зосереджуватися на дослідницькій діяльності учнів. У цьому дослідженні вивчається вплив навчальної моделі 5E на основі ІКТ на концептуальне розуміння та наукові навички учнів 6 класу щодо відбиття світла. Модель 5E розшифровується як «Залучай, досліджуй, пояснюй, розробляй та оцінюй» (Engage, Explore, Explain, Elaborate, and Evaluate). До дослідження, де використовувалась змішана методика, було залучено 24 учні, які брали участь в інтервенції на основі моделі 5E. Результати до і після тестування показали значне покращення концептуальних знань і навичок наукового процесу. Статистичний аналіз з використанням парних t-тестів і критерію Коена показав, що модель 5E значно покращила концептуальне розуміння учнями теми та їхні наукові навички. У дослідженні також використовувався феноменологічний аналіз, який визначив три критичні теми, що сприяли успіху інтервенції. Це високий інтерес і захоплення від використання лабораторних матеріалів, співпраця між учнями в дослідженні відбиття світла, а також підтримка і фасилітація вчителя, щоб допомогти учням подолати труднощі. Модель 5E, у якій передбачено етапи залучення, дослідження, пояснення, розробки та оцінювання, викликала велику зацікавленість учнів і підтримувала їх ентузіазм протягом усього навчання. Дослідження підтверджує, використання моделі 5E сприяє виробленню навчальних навичок та позитивно впливає на розуміння та засвоєння навчального матеріалу. Кількісний та якісний аналіз дає розуміння ефективності інтервенції та пропонує рекомендації щодо покращення впровадження моделі 5E у природничо-наукову освіту. Це дослідження рекомендує надавати вчителям можливості для професійного розвитку, щоб покращити їхні навички у впровадженні навчальної моделі 5E. Регулярні семінари, спільні заняття та можливості для обміну знаннями можуть забезпечити вчителів сучасними стратегіями викладання та ідеями.

Ключові слова: модель 5E; учні загальної середньої освіти; концептуальне розуміння світла; навички наукового процесу; практичне навчання; змішана методика.