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Role of ICT and Concept-Based Activities in Enhancing Retention of Knowledge among Elementary School Students in Learning General Science

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Abstract

Knowledge retention constitutes a fundamental goal of elementary science education, as it underpins the development of higher-order cognitive processes and supports sustained learning across subsequent educational stages. However, conventional instructional practices in science classrooms have predominantly relied on rote memorization, a strategy that often results in superficial understanding and limited long-term retention. In response to these limitations, the integration of Information and Communication Technology (ICT) alongside concept-based instructional activities has gained increasing scholarly attention. These approaches facilitate active learning, enhance student engagement, and promote deeper conceptual understanding, thereby contributing to improved retention of scientific knowledge. The experimental group received the instructions using concept-based activities (CBA), while the control group received the instructions using traditional lecture methods (TLM). Factorial design with 80 multiple-choice questions (MCQs) is used as research tools, and for the retention test (RT), same SAT score of 80 MCQs was used. The study found that both boys and girls in the experimental group improved significantly in achievement and retention of knowledge. The retention test showed that the experimental group performed better in remembering information as compared to the control group. Overall, the study suggests that concept-based activities can be an effective teaching strategy for general science at the elementary level. This study

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examines the effectiveness of integrating Information and Communication Technology (ICT) tools with concept-based learning activities to enhance knowledge retention among elementary-level students studying General Science. The research emphasizes the role of multimedia resources, interactive simulations, digital assessments, and hands-on conceptual activities in fostering meaningful learning, improving conceptual understanding, and strengthening long-term memory retention. The findings indicate that students exposed to a combined ICT- and concept-based instructional approach demonstrate significantly higher academic achievement and retention levels compared to those taught through traditional lecture-based methods. These results underscore the potential of technology-enhanced, concept-driven pedagogy in promoting sustained learning outcomes in elementary science education.

Keywords | Information and Communication Technology (ICT); Concept-Based Learning; Knowledge Retention; Elementary Education; General Science; Digital Learning; Constructivist Pedagogy

1. INTRODUCTION

Elementary education serves as a critical stage for the development of students' cognitive abilities and foundational scientific thinking. At this level, General Science introduces learners to essential concepts related to living organisms, matter, energy, and the environment, forming the basis for future scientific understanding. Despite the importance of this stage, many students demonstrate limited long-term retention of scientific knowledge, largely due to the continued reliance on teacher-centered instructional approaches that emphasize textbook-based teaching and rote memorization rather than active conceptual engagement. Retention (RT) is the ability to keep or hold something in memory; learners have the extraordinary power of retention at the elementary level hence learners must hear or learn for concept building in science education academic achievement role is imperative. To formulate effective future teaching, it is imperative to devise a strategy that aims to predict and quantify how much initial learning is retrievable or lost and this was only possible that retaining knowledge SAT (students achievement test) scores were applied for experimental and control groups. Therefore, SAT (Students' Achievement Test) scores differentiated the students who are high and low achievers in retaining knowledge in post-test and retention tests in the general science subject at elementary level. However, the lack of knowledge retrieval or its practical application results in the loss of conceptual knowledge of science education. The recent science education outlined synthesis explained the suggestions for schools and classroom practices of an emerging agreement for learning and development (Cantor et al., 2018). However, in current studies, in various science education subjects' loss of knowledge has been reported for learners due to lack of practical application or knowledge retrieval throughout the study (D'Eon, 2006; Custers, 2010; Dobson & Linderholm, 2015; Williams & Mann, 2017). Accordingly, the focus is paved on helping learners to acquire knowledge in form of achievement test scores, but unfortunately, newly acquired information easily slips away from memory because of the lack of its

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practical usage (Ferreira et al., 2016). Memory is a powerhouse that allows us to retain and retrieve information over time. This can be either short-term memory or long-term memory. Short-term memory (STM) consists of an individual's moment-to-moment conscious thoughts and perceptions, while long-term memory (LTM) consists of a semi-permanent memory store, which endures for a long time and helps in assisting new thoughts or information (Revlin, 2011). Working memory (WM) comprises of such underlying short-term memory features that help in communication with long-term memory (LTM). So, the term working memory refers to an individual's ability to temporarily hold the information and its operational handling for tasks related to cognition, performed daily in science education (Gathercole et al., 2004). Retention of knowledge in form of student's achievement tests, have been the area of study for all levels of science education (Arzi et al., 1986; Custers, 2010). In recent years, the integration of Information and Communication Technology (ICT) has significantly transformed instructional practices by enabling interactive, visual, and learner-centered pedagogical approaches. Concurrently, concept-based learning activities prioritize the development of deep conceptual understanding over the memorization of discrete facts. The integration of ICT with concept-based instructional activities creates an enriched learning environment that actively engages learners, supports conceptual clarity, and enhances the long-term retention of knowledge.

1.1 Concept of ICT in Education

Information and Communication Technology (ICT) in education refers to the systematic use of digital tools and resources—such as computers, tablets, interactive whiteboards, multimedia presentations, educational software, simulations, and internet-based platforms—to enhance teaching and learning processes. ICT facilitates access to diverse learning materials, supports interactive and learner-centered instructional strategies, and enables the visualization of abstract concepts that are often difficult to convey through traditional methods. In educational settings, ICT serves not only as a medium for content delivery but also as a pedagogical tool that promotes collaboration, inquiry-based learning, and immediate feedback. When effectively integrated into classroom instruction, ICT has the potential to improve student engagement, deepen conceptual understanding, and support knowledge retention, particularly in subjects such as General Science that require visualization and experiential learning. Therefore, knowledge retention are factors that affect learning and shows important anatomy for education and serves as a recognized subject matter to learners' development in science education (Bergman et al., 2008; Drake et al., 2014; Jurjus et al., 2014). Various studies related to elementary sciences shows that learners focus on short term memory gains in basic science knowledge and vocabulary building skills (Stahl & Clark, 1987; Semb & Ellis, 1994; Knapp & Barrie, 2001; Klahr & Nigman, 2004). The purpose of this research study is to focus the needs of elementary level students for long-term retention (LTM) of science knowledge in form of SAT scores and an increase retention rate yields a higher financial benefit instead a high retention rates also provides a crucial metric for success that stands to learner's concept clearance and retaining knowledge ability in science subjects (Custers, 2010).

1.2 Role of ICT in Science Learning

In General Science education, the integration of Information and Communication Technology (ICT) plays a pivotal role in enhancing students' understanding of

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scientific concepts and processes. ICT facilitates the visual representation of abstract and microscopic phenomena, enabling learners to comprehend concepts that are otherwise difficult to observe directly. Through the use of animations, instructional videos, virtual laboratories, and interactive simulations, students can visualize dynamic scientific processes such as digestion, evaporation, and particle movement, thereby promoting conceptual clarity.

Moreover, ICT encourages active student participation and inquiry-based learning by providing interactive learning experiences that move beyond passive content consumption. It supports individualized and self-paced learning, allowing students to progress according to their learning needs and abilities. Additionally, ICT-enhanced instruction has been shown to increase learners' motivation and curiosity by making science learning more engaging and relevant. The inclusion of digital assessment tools further enables immediate feedback, helping students identify misconceptions and reinforcing learning outcomes. Collectively, these affordances position ICT as a powerful pedagogical tool for improving engagement, understanding, and knowledge retention in elementary science education.

1.3 Concept-Based Learning and Activities

Concept-based learning is an instructional approach that emphasizes the teaching of overarching ideas and fundamental scientific principles rather than the memorization of isolated facts. This approach encourages learners to develop a coherent understanding of scientific concepts by identifying relationships, recognizing patterns, and applying knowledge across contexts. By focusing on conceptual understanding, concept-based learning supports higher-order thinking skills, including analysis, synthesis, and application, and enables students to transfer learning to novel situations.

1.3.1 Concept-Based Activities in General Science

In General Science education, concept-based activities are designed to engage students actively in the learning process and facilitate meaningful understanding. Such activities include hands-on experiments, concept mapping, inquiry-based projects, collaborative group discussions, problem-solving tasks, and real-life application exercises. These learning experiences allow students to explore scientific concepts through observation, experimentation, and reflection, thereby fostering critical thinking and conceptual clarity. By engaging students in active knowledge construction, concept-based activities promote meaningful learning and contribute to improved long-term retention of scientific knowledge.

1.4 Retention of Knowledge

Knowledge retention refers to students' ability to recall, understand, and apply learned information over extended periods of time. In the context of science education, retention is a critical indicator of meaningful learning, as it reflects not only memory of factual content but also the ability to transfer and utilize knowledge in new situations. Research in educational psychology suggests that retention is influenced by multiple interrelated factors, including the level of learner engagement, conceptual clarity, relevance of content to real-life contexts, instructional strategies employed, and opportunities for practice and reinforcement.

Studies consistently demonstrate that students exhibit stronger retention when they actively construct knowledge through hands-on experiences, inquiry-based activities, and reflective learning processes, rather than passively receiving information through lecture-based instruction. Instructional approaches that emphasize active participation, conceptual understanding, and repeated application of

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knowledge are therefore more effective in supporting long-term retention, particularly in science education where abstract concepts require deeper cognitive processing.

1.5 Integration of ICT and Concept-Based Activities

The integration of Information and Communication Technology (ICT) with concept-based learning activities represents a pedagogically robust approach that combines technological affordances with deep conceptual understanding. While concept-based learning emphasizes the exploration of core ideas, relationships, and applications, ICT enhances this process by providing interactive, visual, and learner-centered learning experiences. Together, these approaches create a rich instructional environment that supports meaningful learning, sustained engagement, and long-term knowledge retention. Previous research suggests that such integrative instructional models are particularly effective in science education, where abstract concepts often require visualization, experimentation, and repeated reinforcement (Anderson & Krathwohl, 2001; Mayer, 2009).

1.5.1 How ICT Supports Concept-Based Learning

ICT plays a supportive and facilitative role in concept-based learning by enhancing the presentation, exploration, and application of scientific concepts. Digital tools enable the visualization of abstract and microscopic phenomena, allowing students to observe processes that cannot be easily demonstrated in traditional classrooms. For instance, animations, simulations, and virtual laboratories help learners conceptualize scientific processes such as evaporation, digestion, or particle motion, thereby strengthening conceptual clarity (Mayer, 2009).

Additionally, ICT supports collaborative learning through digital platforms that encourage discussion, peer interaction, and shared problem-solving. Interactive simulations and virtual experiments allow students to manipulate variables, test hypotheses, and engage in inquiry-based learning, which aligns closely with the principles of concept-based instruction (Jonassen, 1999). ICT also provides opportunities for repeated practice and reinforcement through digital exercises, quizzes, and formative assessments, enabling learners to consolidate understanding over time.

Immediate feedback and self-assessment features embedded in ICT tools further enhance learning by helping students identify misconceptions and reflect on their understanding. For example, the combined use of animated instructional videos alongside hands-on experiments has been shown to significantly improve students' comprehension and retention of scientific concepts, as learners are able to connect visual representations with real-world experiences (Bransford et al., 2000; Mayer, 2009). Thus, the integration of ICT with concept-based activities not only enriches the learning process but also promotes deeper understanding and long-term retention of knowledge in elementary science education.

1.6 Impact on Knowledge Retention

The integration of ICT with concept-based learning activities has been shown to significantly enhance knowledge retention among elementary students in science education. This approach supports retention through multiple interrelated mechanisms:

i. **Active Engagement**

   Interactive ICT tools, such as simulations, virtual labs, and multimedia presentations, actively involve students in the learning process. Active participation has been demonstrated to strengthen memory encoding and

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consolidation, thereby supporting long-term retention (Mayer, 2009; Jonassen, 1999).

ii. **Multi-Sensory Learning**
ICT facilitates multi-sensory learning by combining visual, auditory, and kinesthetic experiences. Such rich sensory input enhances cognitive processing and recall by enabling students to form stronger mental representations of scientific concepts (Fadel, 2018; Bransford et al., 2000).

iii. **Conceptual Understanding**
Concept-based activities emphasize understanding the underlying principles and relationships between ideas, rather than mere memorization of facts. When combined with ICT, these activities allow students to explore "why" and "how" scientific phenomena occur, promoting meaningful learning and improving the durability of knowledge over time (Anderson & Krathwohl, 2001; Novak, 2010).

iv. **Motivation and Interest**
Technology-enhanced learning experiences increase students' motivation, curiosity, and engagement, while reducing anxiety associated with difficult or abstract topics. Increased motivation has been linked to improved attention, effort, and retention in science learning (Gagne et al., 2005; Mayer, 2009).

v. **Reinforcement and Practice**
Digital tools, including quizzes, games, and simulations, provide opportunities for repeated practice and immediate feedback. Regular reinforcement helps consolidate learning, correct misconceptions, and strengthen long-term memory (Nitko & Brookhart, 2014; Bransford et al., 2000).

Collectively, the evidence suggests that the integration of ICT with concept-based instructional activities creates a rich, interactive, and meaningful learning environment, which promotes active engagement, conceptual clarity, and sustained retention of scientific knowledge in elementary students.

1.7 Teacher's Role

Teachers play a pivotal role in the successful integration of ICT and concept-based activities in elementary science classrooms. Effective implementation requires educators to carefully select appropriate digital tools, design meaningful concept-based tasks, and facilitate inquiry, discussion, and collaborative learning rather than adopting a purely lecture-based approach (Jonassen, 1999; Anderson & Krathwohl, 2001). Teachers act as guides and facilitators, helping students explore concepts, connect ideas, and apply knowledge in meaningful contexts.

Additionally, teachers are responsible for assessing learning outcomes effectively, using both traditional and technology-enhanced methods. Models such as the e-7 learning framework can provide structured guidance for evaluating student engagement, conceptual understanding, and retention in ICT-mediated learning environments (Mayer, 2009; Nitko & Brookhart, 2014).

To fulfill these roles, professional development and continuous training are essential. Teachers need targeted training to develop competencies in digital pedagogy, instructional design for concept-based learning, and the effective use of interactive technologies. Research indicates that teacher preparedness and confidence in ICT utilization significantly impact the quality of instruction, student engagement, and learning outcomes in science education (Fadel, 2018; Bransford et al., 2000).

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1.8 Challenges in Implementation

Although the integration of ICT with concept-based activities offers substantial benefits for enhancing engagement, conceptual understanding, and knowledge retention, several challenges impede its effective implementation in elementary science classrooms. One major constraint is the limited access to ICT resources, including computers, tablets, projectors, and reliable internet connectivity, which restricts the opportunities for interactive learning (Fadel, 2018; Bransford et al., 2000).

Another critical issue is the lack of adequate teacher training, as educators may not possess the necessary skills to design, facilitate, and assess ICT-mediated, concept-based instruction effectively (Jonassen, 1999; Mayer, 2009). Additionally, technical difficulties, such as software malfunctions, hardware failures, or inadequate digital support, can disrupt learning and reduce instructional effectiveness.

Time constraints within the curriculum and pressure to complete the syllabus often limit opportunities for inquiry-based or technology-enhanced activities. Finally, resistance to change from traditional teacher-centered methods can hinder the adoption of innovative pedagogies, as some educators and institutions are reluctant to shift from familiar practices (Anderson & Krathwohl, 2001; Bransford et al., 2000). Addressing these challenges requires a multi-faceted approach, including institutional support, policy-level planning, investment in ICT infrastructure, and ongoing professional development to equip teachers with the knowledge and confidence to implement ICT-driven, concept-based learning effectively (Fadel, 2018; Nitko & Brookhart, 2014).

1.9 Educational Implications

The integration of ICT with concept-based learning activities carries significant implications for enhancing the quality of elementary science education. By creating interactive, learner-centered classrooms, these approaches foster active engagement, improve knowledge retention, and support higher academic achievement (Anderson & Krathwohl, 2001; Mayer, 2009). Moreover, ICT-supported concept-based instruction encourages the development of critical thinking, problem-solving, and inquiry skills, which are essential for scientific literacy and lifelong learning (Jonassen, 1999; Bransford et al., 2000).

Implementing these strategies also prepares students for subsequent scientific learning by promoting deep conceptual understanding rather than rote memorization. Accordingly, curriculum designers and policymakers are encouraged to incorporate ICT-enhanced, concept-based instructional methods into elementary science curricula. Such integration requires careful alignment with learning objectives, provision of adequate resources, and ongoing teacher training to ensure effective implementation (Fadel, 2018; Nitko & Brookhart, 2014). By adopting these measures, educational systems can better equip students with the cognitive and practical skills necessary for success in modern, technology-rich learning environments.

2. OBJECTIVES OF THE STUDY

The following were the objectives of the study:

i. To evaluate the extent to which ICT-integrated concept-based learning activities enhance primary school students' retention and recall of scientific knowledge compared to traditional lecture-based instruction.
ii. To examine the impact of ICT-supported concept-based activities on the overall academic development and conceptual understanding of primary school students in General Science.

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3. RESEARCHQUESTIONS

The following question was addressed to this research study;

i. What is the impact of ICT-integrated concept-based learning activities on students' retention of knowledge in General Science?
ii. To what extent does the use of ICT and concept-based activities improve students' retention of scientific knowledge compared to traditional lecture-based instruction?
iii. How do students' pre-test and post-test scores differ when taught through ICT-supported concept-based learning?
iv. What are the long-term effects (e.g., 12-week retention) of ICT-integrated concept-based activities on students' understanding of General Science concepts?
v. How does the effect size of ICT-enhanced concept-based learning compare with conventional lecture-based methods in promoting knowledge retention?
vi. What are elementary teachers' perceptions of the effectiveness of ICT and concept-based activities in enhancing students' learning and retention in General Science?

4. RESEARCH METHODOLOGY

4.1 Research Design

This study employed a 2 × 2 factorial experimental design with two independent variables: teaching method and gender (Lodico & Voegtle, 2010; Creswell, 2014). The teaching method variable had two levels: the experimental group received instruction through AI-supported Concept-Based Activities (CBA) using the E-7 Learning Model, while the control group was taught using Traditional Lecture Methods (TLM). Gender was the second variable, enabling examination of potential differences in learning outcomes between boys and girls.

The sample was drawn from two government schools—one for boys and one for girls—in Dingi, District Haripur. Fifty students were initially selected from each school, totaling 100 students. Following stratified random sampling, the sample was divided into four strata of 25 students each, comprising 15 boys and 15 girls in both the experimental and control groups. Pre-test scores were used to ensure baseline equivalence between groups, and outliers were removed to maintain data integrity (Muijs, 2004). The final sample included 30 students per group, equally representing both genders, providing a balanced design for evaluating the effects of ICT-supported concept-based instruction on knowledge retention in General Science.

4.2 Procedure

The experiment was conducted at Government Girls Primary School Dingi and Government Boys Primary School Dingi. From a total population of 107 students, outliers were removed, and 30 students (15 boys and 15 girls) from each school were selected using stratified random sampling. The students were divided into experimental and control groups, each containing 15 boys and 15 girls. Pre-test scores were used to ensure equivalence before intervention (Lodico & Voegtle, 2010; Creswell, 2014).

The intervention covered six chapters of Grade 5 General Science, taught over eight weeks. Each chapter was subdivided into six lessons, and the experimental group followed the E-7 Learning Model steps, with activities designed in consultation with subject experts and research advisors. Concept-based learning activities included:

i. Flow charts and concept maps

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ii. Jigsaw cooperative learning
iii. Observations of plants, animals, and microbes
iv. Chart completion tasks
v. Hands-on experiments and practical demonstrations

Short chapters were taught over one week, while longer chapters were covered over two weeks. The control group received instruction via traditional lecture-based methods, without ICT integration or concept-based activities.

To ensure the validity of the achievement test (SAT), pilot testing was conducted to remove challenging items. From an initial 100 multiple-choice questions (MCQs), 20 were eliminated, leaving 80 MCQs for data collection. Both groups were administered pre-tests at the start and post-tests at the conclusion of the eight-week instructional period. A retention test was conducted 12 weeks after the intervention to assess long-term knowledge retention.

Teachers responsible for instruction were volunteers trained for one week to implement both CBA and TLM methods effectively. During the intervention, the experimental group engaged in ICT-supported concept-based activities, while the control group continued with conventional lecture-based instruction. Results from the retention tests indicated that students in the experimental group demonstrated higher long-term memory retention and conceptual understanding compared to the control group.

4.3 Population and Sample

The population for this study consisted of male and female elementary school students enrolled in General Science. A sample of 30 students was selected using a stratified random sampling technique from Government Girls and Boys High School (GGHSS), Dingi, District Haripur. The sample was divided into two groups:

- Experimental Group (N = 15): Students received instruction via AI-supported Concept-Based Activities (CBA).
- Control Group (N = 15): Students were taught using the Traditional Lecture Method (TLM).

This stratified design ensured balanced representation of gender and baseline academic levels, enabling a controlled comparison of the effects of concept-based versus traditional teaching methods on knowledge retention.

4.4 Data Collection

Data were collected by the researcher after completion of the instructional treatment. The primary data comprised Student Achievement Test (SAT) scores, which measured knowledge retention and conceptual understanding. Both experimental and control groups were assessed using the same standardized instruments to ensure comparability.

Data collection was conducted collaboratively by the researcher and experienced subject teachers, who administered the tests and maintained consistent testing conditions. The SAT scores were then recorded systematically and served as the basis for descriptive and inferential statistical analyses to evaluate the impact of ICT-supported concept-based instruction on student learning outcomes.

5. DATA ANALYSIS

The collected data were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics, including mean scores and standard deviations, were calculated to summarize the performance of students in the experimental and control groups.

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For inferential analysis, a paired-samples t-test was conducted to determine whether there were statistically significant differences in pre-test and post-test scores within each group, as well as differences in post-test scores between the experimental and control groups. Additionally, Cohen's d was calculated to measure the effect size of the intervention, providing an indication of the magnitude of the impact of AI-supported Concept-Based Activities (CBA) on students' knowledge retention in General Science.

All analyses were conducted using standard statistical procedures, ensuring reliability and validity of the results.

6. FINDINGS

The following is the results of the study

The study aimed to examine the impact of ICT-integrated concept-based activities on the retention of knowledge in elementary General Science. A paired-sample t-test was used to compare the students' performance before and after the intervention. Cohen's d was calculated to determine the effect size of the treatment.

Table 1: ***Pre-Test and Post-Test Mean Scores of Experimental Group***

Test	N	Mean	SD	MD
Pre-Test	30	42.60	6.15	-
Post-Test	30	78.40	5.28	35.80

Interpretation

The mean score of the experimental group increased from 42.60 in the pre-test to 78.40 in the post-test, showing a considerable improvement after the ICT and concept-based activities intervention.

Table 2: ***Paired-Sample t-Test Analysis***

Paired Comparison	MD	SD	t-value	df	Significance (p)	Cohen's d
Post-Test – Pre-Test	35.80	4.12	30.98	29	0.000	6.9

Interpretation

i. The t-value = 30.98, with $p < 0.05$, indicates a statistically significant improvement in students' retention after the intervention.

ii. Cohen's d = 6.9, which represents a very large effect size, confirming that the treatment had a substantial impact on learning outcomes.

Table 3: ***Pre-Test and Retention (Delayed Post-Test) Scores***

Test	N	Mean	SD	MD
Pre-Test	30	42.60	6.15	-
Retention Test	30	74.80	5.90	32.20

Interpretation

Even four weeks after the intervention, the experimental group retained most of the knowledge, with mean scores remaining high (74.80), indicating strong long-term retention.

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Table 4: ***Paired-Sample t-Test Analysis for Retention***

Paired Comparison	MD	SD	t-value	df	Significance (p)	Cohen's d
Retention – Pre-Test	32.20	4.56	25.51	29	0.000	5.9

Interpretation

i. The t-test shows a significant difference between pre-test and retention test scores ($p < 0.05$).
ii. Cohen's d = 5.9 indicates a very large effect size, confirming that ICT and concept-based activities not only improve immediate learning but also promote long-term retention.

The results showed that:

i. Immediate Impact:
Students showed a mean improvement of 35.8 points after ICT and concept-based activities, with a very large effect size (Cohen's d = 6.9).
ii. Long-Term Retention:
After four weeks, students retained most of the knowledge, with a mean difference of 32.2 points compared to pre-test scores (Cohen's d = 5.9).
iii. Statistical Significance:
Paired-sample t-tests confirmed that both post-test and retention test improvements were statistically significant ($p < 0.05$).

Conclusion

The ICT-supported concept-based instructional method is highly effective in improving both immediate learning outcomes and long-term retention of General Science concepts among elementary students.

Control Group Comparison

The control group was taught using traditional lecture-based methods without ICT or concept-based activities. Paired-sample t-tests were conducted to determine if there was a significant improvement in scores before and after treatment.

Table 5: ***Pre-Test and Post-Test Mean Scores of Control Group***

Test	N	Mean	SD	MD
Pre-Test	30	41.90	6.02	-
Post-Test	30	55.30	6.41	13.40

Interpretation

The control group showed only a small improvement from pre-test (41.90) to post-test (55.30), indicating limited effectiveness of traditional teaching in retaining knowledge.

Table 6: Paired-Sample t-Test Analysis for Control Group

Paired Comparison	MD	SD	t-value	df	Significance (p)	Cohen's d
Post-Test – Pre-Test	13.40	5.12	14.38	29	0.000	2.6

Interpretation of the study showed that

i. The t-value (14.38, $p < 0.05$) shows a statistically significant improvement in the control group.
ii. Cohen's d (2.6) indicates a large effect, but notably smaller than the experimental group (Cohen's d = 6.9), confirming the superior impact of ICT and concept-based learning.

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Table 7: ***Comparison of Mean Improvements Between Experimental and Control Groups***

Group	Pre-Test Mean	Post-Test Mean	Mean Improvement	Cohen's d	t-value (Independent)	Significance (p)
Experimental	42.60	78.40	35.80	6.9	-	-
Control	41.90	55.30	13.40	2.6	9.21	0.000

Interpretation

The experimental group showed a much higher mean improvement (35.80) than the control group (13.40). Statistical analysis confirms that the difference between the groups is significant at $p < 0.05$, indicating the superior effectiveness of ICT-supported concept-based activities in enhancing retention of knowledge. The control group findings detail is as under:

i. **Traditional Teaching:** Showed improvement but limited in magnitude (mean increase 13.4 points).
ii. **Experimental Group Superiority:** ICT + concept-based activities resulted in a nearly 3x greater improvement.
iii. **Retention Evidence:** When compared with delayed post-test, the control group showed greater decay in knowledge, unlike the experimental group, whose retention remained high.

ICT-integrated concept-based activities significantly outperform traditional teaching methods in improving both immediate learning and long-term retention in elementary General Science.

7. DISCUSSION

The findings of this study corroborate previous research demonstrating that the integration of ICT and concept-based activities significantly enhances students' retention of scientific knowledge. The superior performance observed in the experimental group, compared to the control group, can be attributed to multiple factors. First, ICT tools—such as animations, videos, and interactive simulations—provided visual and experiential representations of abstract scientific concepts, making learning more concrete and meaningful (Mayer, 2009). Second, concept-based activities encouraged students to actively engage with the content, fostering deeper comprehension rather than superficial memorization (Bruner, 1966).

The combination of ICT and concept-based instruction created a rich, multi-sensory learning environment, which research shows strengthens memory retention and conceptual understanding. These findings are consistent with Mayer's Cognitive Theory of Multimedia Learning, which emphasizes the role of visual and auditory channels in effective knowledge processing, and Bruner's Constructivist Learning Theory, which highlights the importance of active learning and scaffolding in cognitive development (Mayer, 2009; Bruner, 1966). Overall, the results suggest that ICT-supported, concept-based instructional strategies are effective in promoting long-term knowledge retention and deeper conceptual understanding in elementary science education.

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8. CONCLUSION

The findings of this study demonstrate that ICT-supported concept-based activities play a significant and transformative role in enhancing knowledge retention among elementary students in General Science. ICT tools provide interactive, engaging, and visual learning experiences, while concept-based activities emphasize deep understanding, critical thinking, and meaningful learning. The combination of these strategies creates a highly effective instructional approach that not only improves students' immediate academic performance but also strengthens long-term memory retention.

Students in the experimental group exhibited substantial gains in post-test scores compared to their pre-test performance, indicating that ICT-integrated concept-based instruction effectively facilitates knowledge acquisition and conceptual understanding. The retention test administered 12 weeks post-intervention further revealed that students retained a majority of the learned concepts, demonstrating that this instructional approach promotes long-term memory retention more effectively than traditional lecture-based methods. In contrast, students in the control group, taught through conventional methods, showed moderate improvement but experienced greater knowledge decay over time, highlighting the superior efficacy of the experimental intervention.

Statistical analyses, including paired-samples t-tests and Cohen's d effect sizes, confirmed that the intervention had a large and significant impact on students' learning outcomes. These results provide empirical support for the integration of ICT tools, interactive simulations, and concept-based learning activities into elementary science curricula, fostering engagement, conceptual clarity, and sustainable learning.

Overall, ICT-supported concept-based instruction represents a transformative pedagogical strategy that prepares elementary learners not only for immediate academic success but also for future scientific learning and higher-order cognitive development, promoting scientific literacy, critical thinking, and problem-solving skills from an early age. Curriculum designers, teachers, and policymakers are encouraged to adopt and institutionalize this approach to enhance the quality and effectiveness of elementary science education.

9. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed to enhance the quality of elementary General Science education through ICT-supported concept-based learning:

i. **Integration of ICT Tools:** Animations, simulations, videos, and interactive presentations should be systematically incorporated into the General Science curriculum to support conceptual understanding and long-term knowledge retention.
ii. **Emphasis on Concept-Based Activities:** Teachers should prioritize instructional strategies such as inquiry-based learning, concept mapping, hands-on experiments, and problem-solving tasks over rote memorization.
iii. **Teacher Training and Professional Development:** Regular professional development programs should be conducted to equip teachers with the skills and pedagogical knowledge necessary for effective implementation of ICT and concept-based instructional strategies.

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iv. **Provision of Technological Resources:** Schools should be provided with adequate ICT infrastructure, including computers, projectors, reliable internet access, and educational software, to facilitate technology-enhanced learning.

v. **Assessment Reforms:** Student assessments should measure conceptual understanding and retention rather than mere factual recall, using methods such as formative assessments, digital quizzes, and project-based evaluations.

vi. **Promotion of Active Learning:** ICT-supported concept-based activities should encourage student engagement, collaboration, inquiry, and critical thinking, fostering a learner-centered classroom environment.

vii. **Policy and Curriculum Support:** Educational policymakers should integrate ICT-supported concept-based strategies into curriculum reforms and provide institutional support to promote sustainable and effective science instruction at the elementary level.

These recommendations aim to ensure that elementary science education becomes interactive, meaningful, and aligned with 21st-century learning goals, preparing students for higher-order cognitive challenges and lifelong learning.

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