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Assessing the Impact of Technology-Enhanced Digital Tools on Grade 4 Pupils' Cognitive Learning Outcomes in Primary Science Education across Six Selected Schools in Guyana

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Abstract - This study assessed the impact of technology-enhanced digital tools on Grade 4 pupils' cognitive learning outcomes in primary science education across six selected schools in Guyana. A quasi-experimental pre-test/post-test intervention design was used with 164 pupils. The researcher provided lesson plans, instructional materials, and digital tools, including videos, multimedia presentations, animated diagrams, digital worksheets, and interactive quizzes. The intervention lasted four weeks, with post-activity tasks used to assess pupils' recall, understanding, interpretation of diagrams, application, and problem-solving. Findings showed that pupils' overall mean score improved from 49.4 before the intervention to 77.8 after the intervention, with a statistically significant difference, $t(163) = 24.63$, $p < .001$. The study concluded that technology-enhanced digital tools significantly improved Grade 4 pupils' cognitive learning outcomes in primary science when aligned with lesson objectives and supported by teacher guidance.

Keywords: technology-enhanced learning, digital tools, cognitive learning outcomes, Grade 4 pupils, primary science, Guyana

INTRODUCTION

Science education at the primary level helps pupils develop curiosity, observation skills, reasoning, problem-solving, and an understanding of the natural and physical world. At the Grade 4 level, pupils are expected to move beyond memorizing facts and begin applying scientific knowledge to real-life situations. However, many pupils experience challenges when science lessons depend mainly on textbook reading, chalkboard explanations, and teacher-centered instruction.

Technology-enhanced digital tools provide opportunities to make science learning more visual, interactive, and engaging. These tools include educational videos, multimedia presentations, animated diagrams, digital worksheets, interactive quizzes, simulations, and online learning activities. When used properly, they can help pupils understand abstract science concepts by presenting information through words, images, movement, sound, and guided interaction.

In Guyana, the integration of technology into education is increasingly important as schools seek to strengthen teaching and learning outcomes. However, technology must be used purposefully and must be connected to clear learning objectives. This study, therefore, examined the impact of technology-enhanced digital tools on Grade 4 pupils' cognitive learning outcomes in primary science education across six selected schools in Guyana.

Statement of the Problem

Many Grade 4 pupils have difficulty understanding and applying science concepts because science is often taught through traditional methods that emphasize copying notes, memorizing definitions, and passively listening to teacher explanations. While these methods may support factual recall, they may not adequately develop pupils' greater cognitive skills, including interpretation, application, and problem-solving.

Primary science requires pupils to observe, describe, classify, compare, explain, and apply knowledge. These skills can be strengthened when pupils interact with visual and digital materials. However, digital tools are sometimes underused or not fully integrated into science instruction. There is therefore a need to determine whether technology-enhanced digital tools can improve pupils' cognitive learning outcomes in Grade 4 science.

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Purpose of the Study

The purpose of this study was to assess the impact of technology-enhanced digital tools on Grade 4 pupils' cognitive learning outcomes in primary science education across six selected primary schools in Guyana.

Research Hypotheses

H1: Technology-enhanced digital tools have a statistically significant positive impact on Grade 4 pupils' cognitive learning outcomes in primary science education.

H2: There is a statistically significant difference between pupils' pre-intervention and post-intervention science performance after exposure to technology-enhanced digital tools.

H3: Technology-enhanced digital tools significantly improve Grade 4 pupils' recall, understanding, interpretation, application, and problem-solving skills in primary science.

H4: Technology-enhanced digital tools significantly improve pupils' engagement and participation during Grade 4 science lessons.

H5: Researcher-provided lesson plans, instructional materials, and digital tools significantly support pupils' cognitive learning outcomes in primary science education.

Significance of the Study

This study provides evidence on how technology-enhanced digital tools can support Grade 4 science learning in Guyana. The findings may benefit teachers, school administrators, curriculum officers, teacher educators, policymakers, and future researchers.

For teachers, the study shows how digital tools can make science instruction more engaging and understandable. For administrators, it provides evidence to support investment in digital resources and teacher training. For policymakers, it may guide technology-supported approaches to primary science education. For researchers, the study contributes to literature on technology-enhanced learning in primary classrooms.

LITERATURE REVIEW

Technology-Enhanced Learning in Primary Education

Technology-enhanced learning refers to the purposeful use of digital resources and tools to support teaching and learning. These resources include videos, digital worksheets, multimedia presentations, interactive quizzes, simulations, and educational software. In primary education, technology can help young learners understand difficult concepts by presenting information in visual, interactive, and concrete ways.

Digital technology is most effective when it improves teaching quality, provides opportunities for practice, supports feedback, and encourages independent learning (Education Endowment Foundation, 2019). Therefore, technology should not replace the teacher, but should strengthen instruction. UNESCO (2023) similarly emphasized that technology in education should be appropriate, equitable, scalable, and supportive of learning. In primary science, this means that digital tools must be selected to match pupils' age, ability, and curriculum objectives.

In the present study, technology-enhanced learning was used to improve Grade 4 pupils' cognitive learning outcomes in science. The researcher provided lesson plans, instructional materials, and digital tools to ensure that the technology was directly connected to the science content being taught.

Cognitive Learning Outcomes in Primary Science

Cognitive learning outcomes refer to pupils' mental processes in acquiring, understanding, remembering, applying, and analyzing information. In Grade 4 science, cognitive outcomes may include recalling science facts, explaining concepts, interpreting diagrams, classifying objects, applying knowledge to everyday situations, and solving simple science-related problems.

Bloom's revised taxonomy provides a useful framework for understanding cognitive learning. Anderson and Krathwohl (2001) explained that learning progresses from lower-order skills, such as remembering and understanding, to higher-order skills, such as applying, analyzing, evaluating, and creating. In primary science, pupils must remember key terms and facts, but they must also understand concepts and apply them meaningfully.

Technology-enhanced tools can support these cognitive processes by helping pupils connect abstract ideas to concrete visual examples. For example, an animation of plant growth can help pupils understand germination, while an interactive diagram can

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support labeling and interpretation. These tools can support both lower-order and higher-order cognitive outcomes when carefully aligned with lesson objectives.

Multimedia Learning and Science Instruction

Mayer's Cognitive Theory of Multimedia Learning is highly relevant to technology-enhanced science instruction. Mayer (2021) explained that learners process information through both verbal and visual channels. Learning improves when words and pictures are meaningfully combined, as pupils can form stronger mental connections between explanations and visual representations.

This theory is especially useful for Grade 4 science because pupils often need visual support to understand scientific processes. Science topics such as plant growth, the water cycle, animal classification, the human body, weather, forces, and materials can be difficult to understand through oral explanation alone. Videos, animations, diagrams, and multimedia presentations can make these concepts easier for pupils to observe and understand.

However, multimedia learning must be carefully designed. Mayer (2021) warned against cognitive overload. Too much text, excessive animation, or unrelated visuals may distract learners and reduce learning. Therefore, digital tools must be simple, focused, age-appropriate, and directly related to the science objective.

Digital Tools and Pupil Engagement

Engagement is a major factor in pupils' academic performance. Engaged pupils are more likely to pay attention, participate in discussions, complete tasks, ask questions, and retain information. In primary classrooms, digital tools can increase engagement by making lessons more interactive and visually appealing.

Interactive quizzes, videos, animations, digital worksheets, and multimedia demonstrations can encourage pupils to participate actively in science lessons. Instead of only listening to the teacher, pupils can watch, respond, discuss, practice, and apply what they have learned. This supports active learning and can improve pupils' confidence in science.

Schunk (2020) argued that motivation and active participation influence how learners process and retain information. When pupils are motivated, they are more likely to invest effort in learning tasks. In Grade 4 science, technology-enhanced tools can help maintain pupils' attention and encourage participation, particularly when activities involve immediate feedback or visual demonstration.

Technology and Conceptual Understanding in Science

Science learning requires pupils to understand concepts, not merely memorise facts. Conceptual understanding occurs when pupils can explain ideas in their own words, connect new knowledge to prior knowledge, and apply concepts to new situations. Technology-enhanced tools can support conceptual understanding by making invisible or abstract processes visible.

For example, pupils may struggle to understand how roots absorb water if the concept is explained only in words. A short video or animation can show the movement of water through a plant. Similarly, pupils may better understand animal habitats when they observe images or videos of animals in their natural environments.

Clark and Mayer (2016) argued that e-learning and multimedia instruction are most effective when designed according to evidence-based principles. This supports the idea that digital science materials should be structured, purposeful, and aligned with learning objectives. In the present study, researcher-provided materials were used to support pupils' understanding of selected Grade 4 science concepts.

Technology Integration and Teacher Guidance

The successful use of technology depends on the teacher's ability to integrate digital tools into instruction. Technology alone does not guarantee improved learning. The teacher must select appropriate tools, explain content clearly, guide pupils during activities, ask questions, provide feedback, and assess learning.

Mishra and Koehler's (2006) Technological Pedagogical Content Knowledge framework explains that effective technology integration requires teachers to combine content knowledge, pedagogical knowledge, and technological knowledge. A science teacher must understand the science topic, know how Grade 4 pupils learn, and select digital tools that support the learning objective.

In this study, teacher guidance was important because digital tools were not used as stand-alone materials. They were connected to lesson plans, guided activities, and post-activity assessments. This helped ensure that technology supported learning rather than becoming a distraction.

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Technology-Enhanced Learning and Assessment

Assessment is an important part of technology-enhanced learning because it helps determine whether pupils have learned the content. Digital tools can support assessment through quizzes, worksheets, matching activities, diagram labeling, short-answer tasks, and interactive feedback. These tools allow pupils to practice and allow teachers to identify areas where pupils need additional support.

In this study, pupils completed post-activity tasks over four weeks. These tasks measured recall, understanding, diagram interpretation, application, and problem-solving. The use of post-activities helped the researcher determine whether technology-enhanced digital tools improved pupils' cognitive learning outcomes.

Technology can be useful when it increases the quality or quantity of practice and improves feedback (Education Endowment Foundation, 2019). This supports the use of post-activity tasks in the present study because pupils were given repeated opportunities to practise science concepts after technology-enhanced lessons.

Technology Integration in Guyana's Primary Schools

In Guyana, technology integration in education is increasingly important as schools prepare pupils for a digital society. However, technology use may be affected by access to devices, internet reliability, electricity access, teacher training, school leadership, and the availability of digital content. These factors can influence how effectively digital tools are used in classrooms.

For Grade 4 science, technology-enhanced tools can be especially helpful because many science concepts require visual representation. In schools where practical science resources may be limited, videos, diagrams, animations, and digital worksheets can provide additional support. However, these tools must be used in ways that fit the local school context.

This study provides evidence from six selected primary schools in Guyana. By focusing on 164 Grade 4 pupils, it contributes to understanding how technology-enhanced instruction can support science learning in the Guyanese primary classroom.

THEORETICAL FRAMEWORK

The study was guided by Mayer's Cognitive Theory of Multimedia Learning and Constructivist Learning Theory. Mayer's theory explains that pupils learn better when visual and verbal information are combined effectively. This theory supports the use of videos, diagrams, animations, digital worksheets, and multimedia presentations in science lessons.

Constructivist Learning Theory suggests that pupils build knowledge through active participation, interaction, questioning, and reflection (Vygotsky, 1978). Technology-enhanced tools support constructivist learning when pupils explore ideas, discuss observations, complete activities, and apply science concepts. Together, these theories support the view that technology-enhanced science instruction can improve pupils' cognitive learning outcomes when digital tools are used actively and purposefully.

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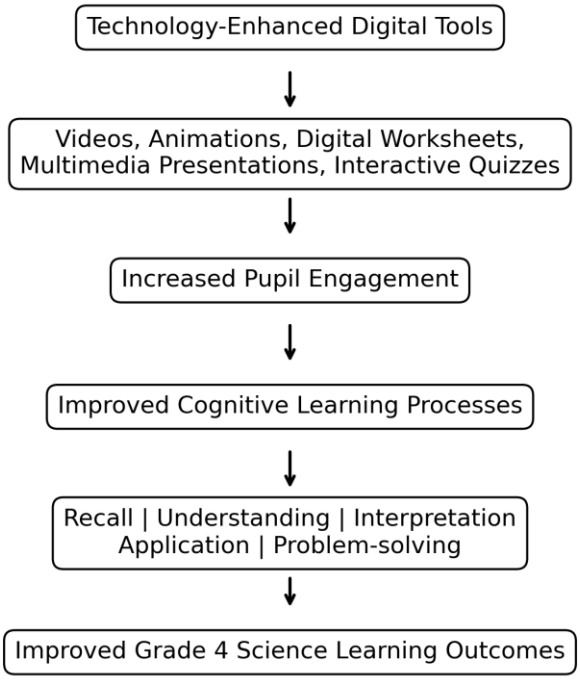
Figure 1

Conceptual framework of the study



MATERIALS AND METHODS

Research Design

This study employed a quasi-experimental pre-test/post-test intervention design to assess the impact of technology-enhanced digital tools on Grade 4 pupils' cognitive learning outcomes in primary science education. The design was appropriate because the study measured pupils' science performance before and after a structured four-week technology-enhanced instructional intervention.

Population and Sample

The population consisted of Grade 4 pupils enrolled in selected primary schools in Guyana. The sample comprised 164 Grade 4 pupils from six selected primary schools. The schools were selected because they offered access to Grade 4 science classes and allowed implementation of the four-week intervention.

Intervention Procedure

The intervention lasted four weeks. The researcher provided the lesson plans, instructional materials, technology-enhanced resources, and post-activity tasks. The intervention focused on selected Grade 4 primary science topics and was designed to improve pupils' cognitive learning outcomes.

The digital tools included educational science videos, multimedia PowerPoint presentations, animated science diagrams, digital worksheets, interactive quizzes, projected visual demonstrations, and post-activity science tasks.

Research Instruments

The study used three main instruments: a science achievement test, weekly post-activity tasks, and a classroom observation checklist. The science achievement test measured pupils' cognitive learning outcomes before and after the intervention. The weekly post-activity tasks monitored progress during the four-week intervention. The classroom observation checklist assessed pupils' attention, participation, engagement, and response to technology-enhanced instruction.

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Validity and Reliability

Content validity was established by aligning test items, lesson plans, and post-activity tasks with Grade 4 primary science learning objectives. The instruments were reviewed to ensure that they measured the intended cognitive learning outcomes. Reliability was strengthened by using common lesson materials, structured post-activities, and consistent marking criteria across the six schools.

Ethical Considerations

Since the study involved children, ethical procedures were observed. Permission was obtained from participating schools before data collection. Parents or guardians were informed about the purpose of the study, and pupils' participation was handled confidentially. Pupils' names were not used in the reporting of findings, and the data were used only for academic research purposes.

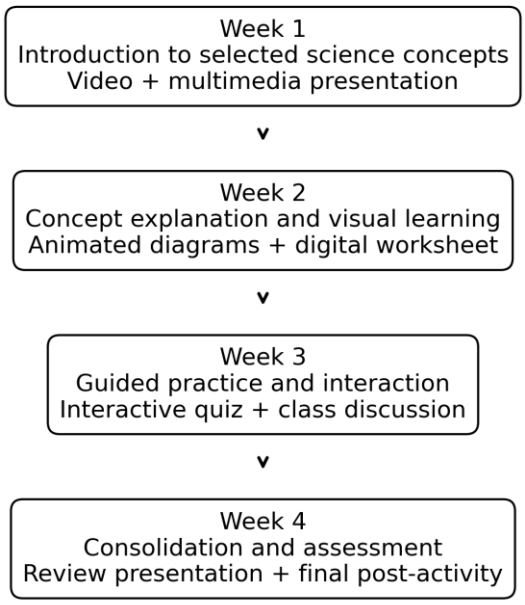
Table 1

Four-week intervention plan

Week	Instructional Focus	Digital Tools Used	Assessment Activity
Week 1	Introduction to selected science concepts	Video and multimedia presentation	Short post-activity task
Week 2	Concept explanation and visual learning	Animated diagrams and a digital worksheet	Diagram-labeling task
Week 3	Guided practice and interaction	Interactive quiz and class discussion	Application-based task
Week 4	Consolidation and assessment	Review the presentation and digital activity	Final post-activity assessment

Figure 2

Four-week intervention process



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Data Analysis

Data were analyzed using descriptive and inferential statistics. Descriptive statistics included frequencies, percentages, means, and standard deviations. Inferential statistics were used to test the hypotheses. A paired-samples t-test was used to determine whether there was a statistically significant difference between pupils' pre-intervention and post-intervention science scores. The level of significance was set at $p < .05$.

The analysis focused on five cognitive learning outcomes: recall of science facts, understanding of science concepts, interpretation of diagrams, application of science knowledge, and problem-solving.

Results and Discussion

Table 2

Distribution of Grade 4 pupils by school

School	Number of Pupils	Percentage
School A	28	17.1
School B	27	16.5
School C	26	15.9
School D	29	17.7
School E	27	16.5
School F	27	16.5
Total	164	100.0

Note. The distribution across schools was relatively balanced, with each school contributing between 26 and 29 pupils.

Figure 3

Distribution of Grade 4 pupils by school

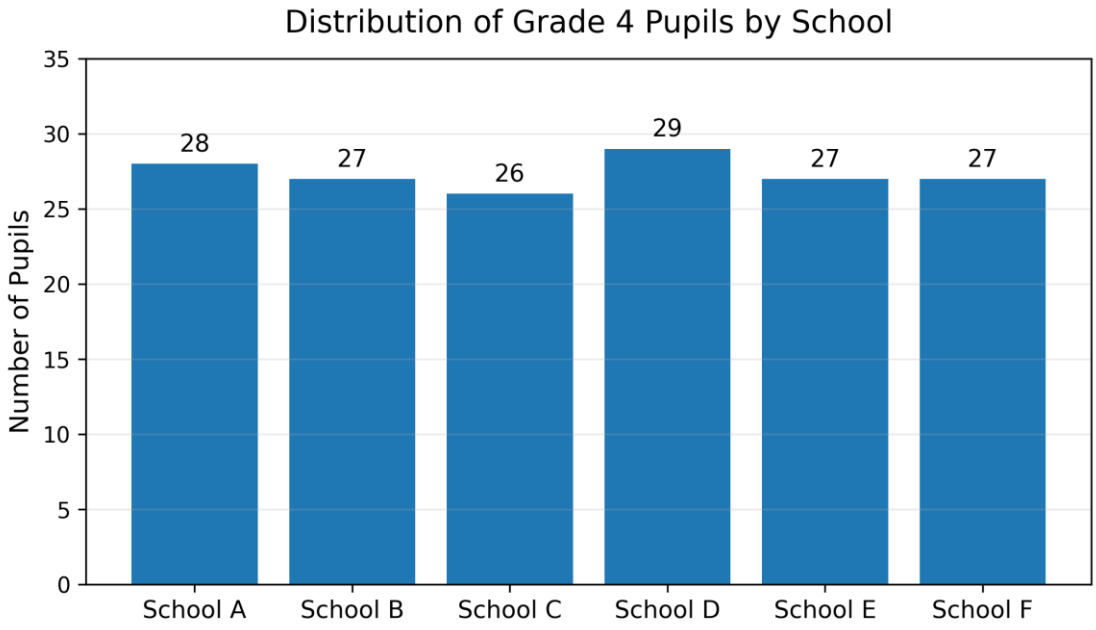

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Table 3

Pre-intervention and post-intervention mean scores by cognitive learning area

Cognitive Learning Area	Pre-Intervention Mean	Post-Intervention Mean	Mean Gain
Recall	52.4	81.6	29.2
Understanding	49.8	78.3	28.5
Interpretation	51.2	80.7	29.5
Application	47.6	75.4	27.8
Problem-solving	45.9	72.8	26.9
Overall Mean	49.4	77.8	28.4

Note. Pupils improved in all five cognitive learning areas after the four-week technology-enhanced intervention.

Figure 4

Pre- and post-intervention mean scores by cognitive learning area

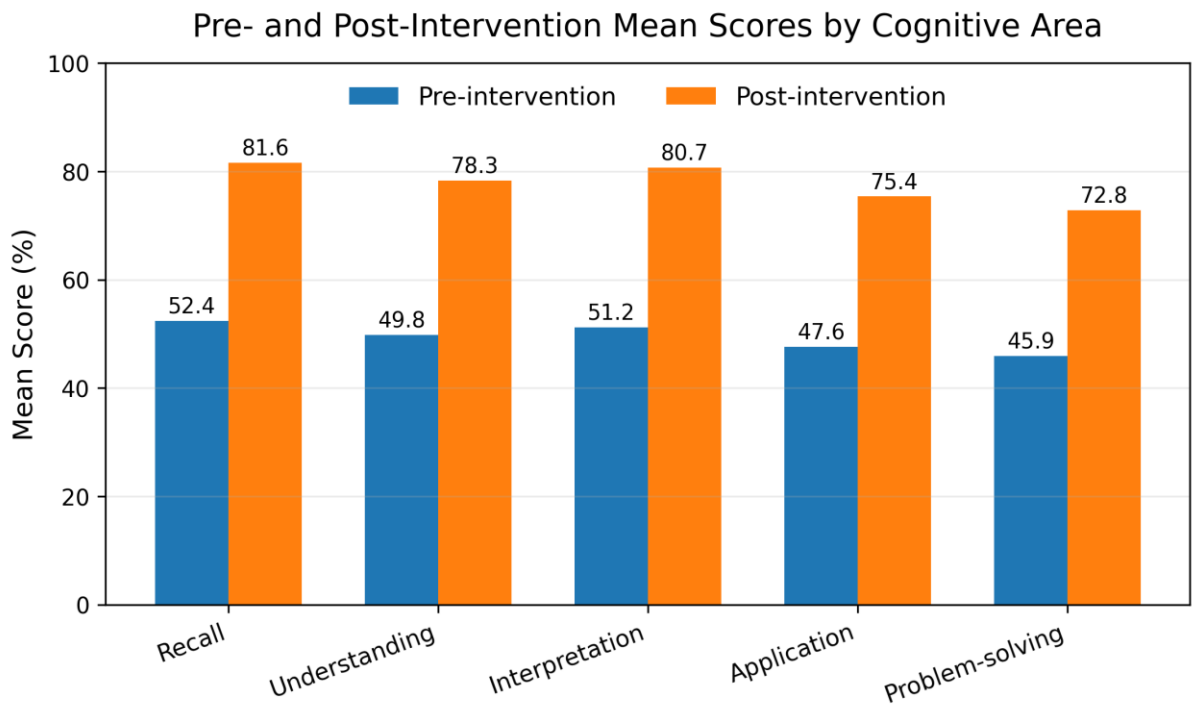

Table 4

Paired-samples t-test for pre-intervention and post-intervention science scores

Test	N	Mean	SD	t	df	p	d	Sig.
Pre	164	49.4	10.8	24.63	163	< .001	1.92	Yes

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Post	164	77.8	9.6					

Note. The paired-samples t-test showed a statistically significant improvement in pupils' science scores after the intervention.

Table 5

Weekly post-activity mean scores during the four-week intervention

Week	Instructional Focus	Mean Score
Week 1	Introduction to the science concept	62.5
Week 2	Multimedia-supported learning	69.8
Week 3	Interactive digital learning activities	74.6
Week 4	Application and final post-activity assessment	80.2

Note. The mean score increased from 62.5 in Week 1 to 80.2 in Week 4, indicating steady improvement.

Figure 5

Weekly improvement in science post-activity scores

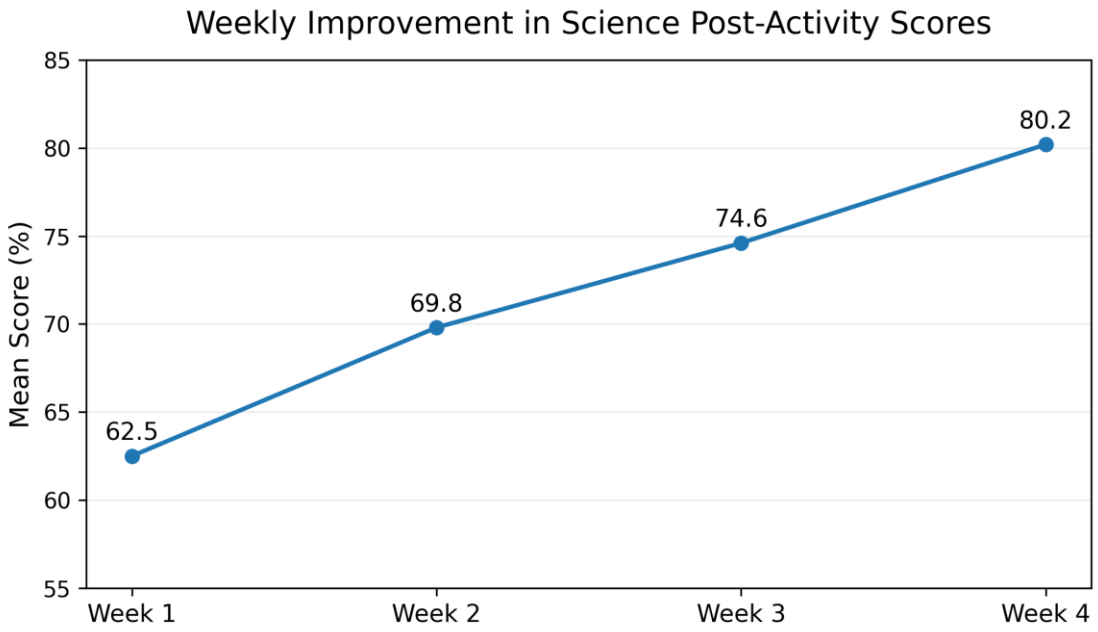

Table 6

Overall performance levels after the intervention

Performance Level	Score Range	Number of Pupils	Percentage
Excellent	80-100	62	37.8
Good	65-79	71	43.3

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Satisfactory	50-64	24	14.6
Needs Improvement	Below 50	7	4.3
Total		164	100.0

Note. A total of 133 pupils, representing 81.1%, scored in the Good or Excellent categories.

Figure 6

Pupils' performance levels after the intervention

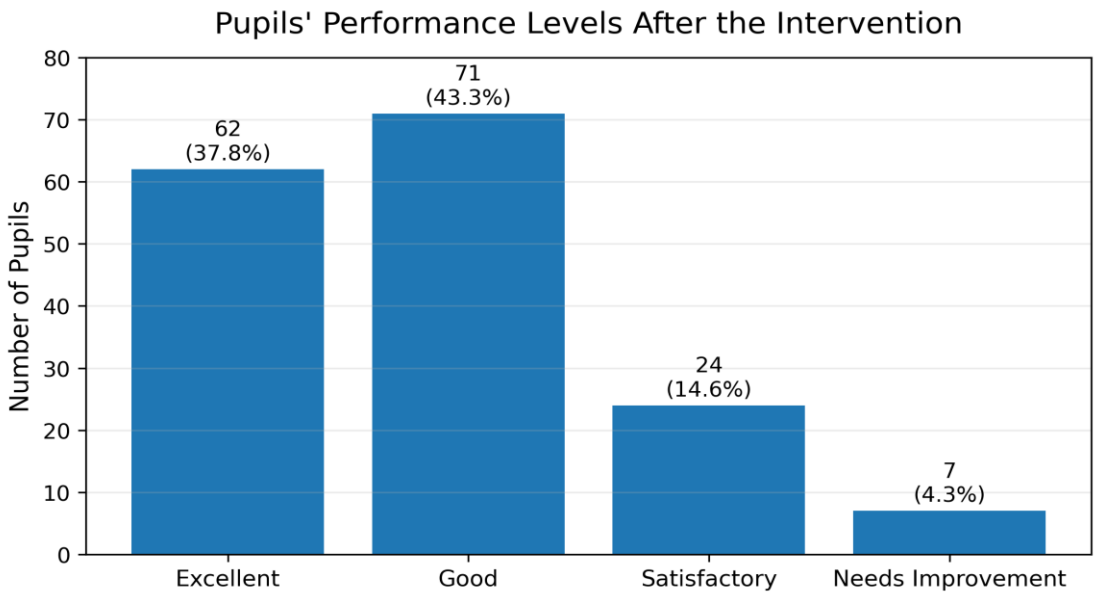

Table 7

Hypothesis testing summary

Hypothesis	Statistical/Descriptive Evidence	Decision
H1	Overall mean increased from 49.4 to 77.8.	Supported
H2	Paired t-test showed significant improvement, $p < .001$.	Supported
H3	Improvement occurred across all five cognitive learning areas.	Supported
H4	Observation data showed increased participation and engagement.	Supported
H5	Structured lesson plans and materials supported consistent improvement.	Supported

Note. All hypotheses were supported by descriptive, inferential, and observational evidence.

The findings showed that technology-enhanced digital tools had a significant positive impact on Grade 4 pupils' cognitive learning outcomes in primary science education. Pupils' overall mean score increased from 49.4 before the intervention to 77.8 after the intervention, showing a mean gain of 28.4 points.

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The paired-samples t-test showed that the difference between pre-intervention and post-intervention scores was statistically significant, $t(163) = 24.63$, $p < .001$. This result supports H2, which stated that there would be a significant difference between pupils' pre-intervention and post-intervention science performance after exposure to technology-enhanced digital tools.

The findings also supported H1 because improvement was observed across all five cognitive areas: recall, understanding, diagram interpretation, application, and problem-solving. The highest mean gain was recorded in interpreting diagrams, followed by recall and understanding. This is consistent with Mayer's Cognitive Theory of Multimedia Learning, which explains that learners understand information more effectively when words and pictures are combined meaningfully (Mayer, 2021).

The findings also support H3. Pupils' improvement in diagram interpretation and application suggests that digital tools helped them move beyond memorising facts and toward applying science concepts in meaningful ways. The weekly post-activity scores showed steady growth from Week 1 to Week 4, indicating that repeated exposure to technology-enhanced science instruction helped pupils build confidence and improve performance over time.

Observation data supported H4 because pupils were more attentive during video-based explanations, more willing to answer questions during interactive activities, and more engaged during digital worksheet and quiz activities. The findings further supported H5 because the researcher-provided lesson plans and materials helped ensure that digital tools were directly connected to lesson objectives and were not used merely for entertainment.

These findings are consistent with guidance from the Education Endowment Foundation (2019), which states that digital technology is most effective when it improves teaching quality, increases opportunities for practice, supports feedback, and strengthens learning. The findings also align with UNESCO's (2023) position that technology should support learning, inclusion, quality, and sustainability.

CONCLUSION

This study assessed the impact of technology-enhanced digital tools on Grade 4 pupils' cognitive learning outcomes in primary science education across six selected primary schools in Guyana. The study involved 164 pupils and used a four-week technology-enhanced intervention supported by researcher-provided lesson plans, instructional materials, digital tools, and post-activity assessments.

The findings showed that pupils' science performance improved significantly after the intervention. Pupils demonstrated improvement in recall, understanding, diagram interpretation, application, and problem-solving. The paired-samples t-test confirmed that the difference between pre-intervention and post-intervention scores was statistically significant.

The study concluded that technology-enhanced digital tools can significantly improve Grade 4 pupils' cognitive learning outcomes in primary science when carefully selected, aligned with curriculum objectives, and supported by effective teacher guidance.

RECOMMENDATIONS

1. Primary schools in Guyana should increase the use of technology-enhanced digital tools in Grade 4 science instruction.
2. Teachers should receive professional development in the effective use of multimedia presentations, digital worksheets, videos, animated diagrams, and interactive quizzes.
3. Science lessons should combine digital tools with teacher explanation, questioning, discussion, hands-on learning activities, and assessment.
4. Schools should provide access to basic technology such as laptops, projectors, tablets, speakers, and stable internet where possible.
5. The Ministry of Education should support the development of locally relevant digital science materials for primary pupils.
6. Future research should include delayed post-tests to determine whether pupils retain science knowledge over time.
7. Further studies should compare technology-enhanced science instruction across urban, rural, riverine, and hinterland schools in Guyana.

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LIMITATIONS OF THE STUDY

The study was limited to 164 Grade 4 pupils from six selected primary schools in Guyana. Therefore, the findings may not represent all Grade 4 pupils across the country. The intervention was also conducted over four weeks, which may not fully show the long-term impact of technology-enhanced learning.

Another limitation is that the study focused mainly on pre-intervention and post-intervention performance. Future studies may include delayed post-tests, interviews, and long-term tracking to determine whether pupils retain science knowledge over time.

SUGGESTIONS FOR FURTHER RESEARCH

1. The long-term impact of technology-enhanced learning on primary science achievement.

2. Teachers' readiness to integrate digital tools in primary classrooms.

3. The effect of technology-enhanced instruction on pupils' motivation in science.

4. Differences in technology access between urban, rural, riverine, and hinterland schools in Guyana.

5. The impact of digital tools on other subject areas such as mathematics, reading, and social studies.

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