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Adapting Science Teaching Along 21ST Century Skills Through Technology Based Strategies In Congressional District IV OF Batangas Province

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Abstract

This study examined how the integration of technology-based strategies in Science instruction supported the development of 21st century skills among learners in Congressional District IV of Batangas Province. It focused on assessing the level of technology integration and its relationship with students' manifestation of critical thinking, problem solving, and collaborative learning skills. The study also explored challenges faced by teachers and proposed strategies to improve Science instruction. Using a descriptive-correlational research design, both quantitative and qualitative data were collected from 158 Science teachers through survey questionnaires and interviews with 10 selected participants. Stratified random sampling ensured representative participation across public and private secondary schools during the school year 2025–2026.

Findings revealed that technology integration in Science instruction was moderately manifested in terms of digital tool availability, teacher preparedness, and student engagement. Significant relationships were found between digital tools and teacher digital literacy with students' development of 21st-century skills, while student access and engagement showed limited relationship. Key challenges included poor internet connectivity, limited device access, insufficient teacher training, technical disruptions, and varying levels of student digital literacy.

Based on these findings, the study recommended the implementation of targeted strategies such as enhancing digital infrastructure, providing continuous professional development for teachers, and promoting student digital inclusion. These interventions aim to strengthen technology integration, enrich Science instruction, and foster deeper learning aligned with 21st-century competencies.

Keywords: *technology integration, science education, digital literacy, 21st-century skills, student engagement*

Introduction

Science education plays a vital role in equipping learners with the knowledge and skills necessary to address complex real-world problems. In the 21st century, students are expected not only to understand scientific concepts but also to develop essential competencies such as critical thinking, problem-solving, collaboration, and digital literacy. However, despite ongoing curriculum reforms and instructional innovations, many learners still struggle to apply scientific knowledge in meaningful contexts, indicating gaps in instructional delivery and learning experiences.

The integration of technology in education has emerged as a powerful approach to address these challenges. Technology-based strategies, including digital simulations, virtual laboratories, and interactive platforms, enable students to engage in inquiry-based and learner-centered activities. According to Espinosa et al. (2023), digital tools enhance analytical thinking and deepen conceptual understanding by allowing learners to explore scientific phenomena in dynamic environments. Similarly, Li and Tsai (2020) emphasized that technology integration supports the development of higher-order thinking skills, particularly in Science education.

The effectiveness of technology integration, however, largely depends on teachers' digital literacy and preparedness. Abella (2023) highlighted that teachers' competence in using digital tools significantly influences instructional quality and student learning outcomes. Teachers who are equipped with both technological and pedagogical skills are better able to design meaningful learning experiences that foster 21st-century skills. In support of this, Pizarro et al. (2024) found that teachers with higher levels of digital competence demonstrate more effective teaching practices and improved student engagement.

Despite its advantages, the implementation of technology in education continues to face several challenges. Bećirović (2023) identified barriers such as inadequate infrastructure, limited access to digital devices, insufficient training, and lack of institutional support. These issues are particularly evident in developing contexts, where disparities in access to technology create unequal learning opportunities. Furthermore, Norris and Soloway (2020) argued that access to technology alone does not guarantee improved learning outcomes; rather, its effectiveness depends on how it is integrated into instructional practices.

In addition, effective technology integration must be grounded in sound pedagogical principles. Zhang and Liu (2020) emphasized that technology-enhanced learning environments are most effective when teachers provide structured guidance and facilitate collaborative learning. This underscores the importance of aligning technology use with appropriate teaching strategies to achieve meaningful learning outcomes.

This study is anchored on the TPACK framework by Mishra and Koehler (2006), which emphasizes that effective technology integration in teaching results from the combination of content, pedagogy, and technology knowledge to improve instruction. Constructivist Learning Theory supports this by highlighting that learners construct knowledge through active

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engagement, which is strengthened through technology-based, student-centered learning. The SAMR Model explains technology integration from enhancement to transformation of learning tasks, while the 21st Century Skills Framework identifies critical thinking, problem-solving, collaboration, and digital literacy as key outcomes of technology-enhanced learning. Together, these frameworks suggest that effective technology use depends on teachers' competence in integrating pedagogy, content, and technology. In this study, TPACK is used to examine how teachers' digital literacy and preparedness influence technology-based strategies and students' 21st-century skills.

Given these considerations, this study aims to investigate the integration of technology-based strategies in Science instruction and its influence on students' 21st-century skills in secondary schools in Congressional District IV of Batangas Province. Specifically, it examines the level of technology integration in terms of digital tool availability, teacher preparedness, and student engagement, and determines its relationship with students' critical thinking, problem-solving, and collaborative learning skills. Furthermore, it explores the challenges encountered by teachers in integrating technology into Science instruction.

Research Questions

Specifically, this study sought to answer the following questions:

1. How may the current level of integration of technology-based strategy in Science classes be assessed by the teachers in terms off:
    - 1.1 availability of digital tools and resources;
    - 1.2 teachers' digital literacy and preparedness;
    - 1.3 students' accessibility and engagement?
2. What is the extent of manifestation of students learning along 21st century skills in Science curriculum as assessed by the respondent relative to:
    - 2.1 enhancing critical thinking;
    - 2.2 improving problem solving abilities; and
    - 2.3 promoting collaborative learning?
3. Is there a significant relationship between the assessments on the level of technology integration and on the extent of manifestation of students learning along the 21st century skills?
4. What challenges are encountered by the teachers in integrating technology-based strategies into Science instruction?
5. Based on the findings, what technology-based strategies may be proposed to improve Science instruction?

Methodology

Research Design

This study employed a descriptive-correlational research design to examine the relationship between technology integration and the development of 21st-century skills among students. This design allowed the researcher to describe current conditions and determine significant relationships between variables without manipulating them.

Participants

The participants of the study consisted of 158 Science teachers from public and private secondary schools in Congressional District IV of Batangas Province during the school year 2025–2026. A stratified random sampling technique was used to ensure representation across different schools.

Research Instrument

Data were collected using a structured survey questionnaire and an interview guide. The instruments were reviewed and validated to ensure clarity and relevance. The instrument measured:

- Level of technology integration in teaching
- Teachers' digital literacy and preparedness
- Availability and accessibility of technological resources
- Students' engagement and development of 21st-century skills (e.g., critical thinking, collaboration, communication, and creativity)

The questionnaire consisted primarily of Likert-scale items to allow quantitative analysis. Additionally, a semi-structured interview guide was utilized to gather in-depth qualitative data on teachers' experiences, challenges, and perceptions regarding technology integration in the classroom.

Data Collection Procedure

Permission to conduct the study was secured from the appropriate school authorities. The validated questionnaire was distributed to selected Science teachers, either in printed or digital format. Respondents were given sufficient time to complete the instrument, and responses were collected and checked for completeness.

Following the survey, selected participants were invited for interviews to further explore their experiences and insights. Interviews were conducted at convenient times, recorded with consent, and transcribed for analysis.

Data Analysis

Descriptive statistics, including frequency, percentage, mean, and standard deviation, were used to determine the level of technology integration and students' 21st-century skills development. Pearson correlation coefficient (r) was employed to examine the relationship between technology integration and the development of students' skills. Qualitative data from interviews were analyzed using thematic analysis to identify recurring patterns, themes, and key challenges in technology integration.

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Results

Section 1: Level of Utilization of Technology-Based Strategy in Science Classes Assessed by the Teachers

Table 1.1 Availability of Digital Tools and Resources

Statements	WM	VI	R
1.Digital projectors or interactive whiteboards are available in our Science classrooms.	3.04	MI	8
2.Desktop computers or laptops are accessible for student use during Science lessons	3.01	MI	9
3.There is reliable internet access in the classroom to support digital learning activities.	2.99	MI	10
4.Educational software and applications relevant to Science are readily available for classroom use.	3.11	MI	6
5.The school provides mobile devices (e.g., tablets, smartphones) for teaching Science lessons when needed	3.07	MI	7
6.There are sufficient multimedia resources (e.g., videos, animations, simulations) to support Science topics.	3.37	MI	2
7.Students are allowed to use their own digital devices to access Science learning materials.	3.39	MI	1
8.Online platforms or learning management systems (e.g., Google Classroom, LMS) are utilized in Science instruction.	3.27	MI	3
9.Digital laboratory tools (e.g., sensors, virtual labs) are used to enhance scientific investigations.	3.18	MI	5
10. The school maintains and updates its digital tools and resources used in Science classes regularly.	3.25	MI	4
Composite Mean	**3.17**	**MI**	

Table 1.1 showed that digital tools in Science instruction are moderately implemented (Composite Mean = 3.17). The highest-rated indicator was students' use of personal devices (WM = 3.39), followed by availability of multimedia resources (WM = 3.37) and use of online platforms (WM = 3.27).The lowest-rated indicators were internet reliability (WM = 2.99) and

access to computers/laptops (WM = 3.01). Overall, digital resources are present but limited by infrastructure constraints.

Section 1: Level of Utilization of Technology-Based Strategy in Science Classes Assessed by the Teachers

Table 1.2 Teachers' Digital Literacy and Preparedness

Statements *As a Science teacher, I…*	**WM**	**VI**	**R**
1. feel confident using various digital tools to support my Science instruction.	3.36	MI	9
2. effectively incorporate multimedia presentations (e.g., PowerPoint, videos) in teaching scientific concepts.	3.51	HI	1
3. regularly use online platforms (e.g., Google Classroom, LMS) to share learning resources with my students.	3.31	MI	10
4. utilize educational apps and simulations that are relevant to the Science curriculum.	3.40	MI	7
5. am capable of addressing basic technical issues that may arise during technology-based instruction.	3.49	MI	2
6. have attended seminars, webinars, or training programs related to technology integration in teaching.	3.41	MI	5.5
7. design Science learning activities that actively involve the use of digital tools and resources.	3.41	MI	5.5
8. make thorough preparations when planning lessons that incorporate digital technology.	3.43	MI	4
9. apply digital-based assessment tools (e.g., online quizzes, interactive tasks) to measure student performance.	3.39	MI	8
10. teach and promote responsible and ethical use of technology among my students.	3.47	MI	3
Composite Mean	**3.42**	**MI**	

The data show that teachers' digital literacy and preparedness are moderately integrated (Composite Mean = 3.42). The highest-rated indicator is use of multimedia presentations (WM = 3.51), followed by basic technical troubleshooting (WM = 3.49) and promotion of responsible technology use (WM = 3.47). Mid-ranked indicators include lesson preparation using technology (WM = 3.43), participation in trainings and design of digital activities (WM = 3.41), and use of educational apps (WM = 3.40).The lowest-rated indicators are confidence in using various digital tools (WM = 3.36) and use of online platforms (LMS) (WM = 3.31). Overall, teachers demonstrate adequate readiness, with stronger skills in multimedia use and weaker consistency in platform utilization.

Section 1: Level of Utilization of Technology-Based Strategy in Science Classes Assessed by the Teachers

Table 1.3 Accessibility and Engagement

Statements	WM	VI	R
1.Have regular access to digital devices (e.g., tablets, laptops, smartphones) for Science-related activities.	3.33	MI	6
2. Have stable internet connectivity to access online Science resources.	3.22	MI	10
3. Have stable internet connectivity to access online Science resources.	3.3	MI	8
4. Show interest in using educational apps and online platforms in learning Science.	3.38	MI	4
5. Complete digital-based assignments and tasks on time.	3.29	MI	9
6. Can independently navigate online learning platforms (e.g., LMS, Google Classroom) for Science activities.	3.32	MI	7
7. Participate more during Science lessons when technology is integrated.	3.46	MI	2
8. Understand complex Science concepts through digital tools	3.41	MI	3
9. Collaborate with peers effectively through digital platforms or tools.	3.37	MI	5
10. Demonstrate motivation and enthusiasm when technology is used in classroom discussions or activities.	3.59	HI	1
Composite Mean	**3.37**	**MI**	

The data show that students' engagement and accessibility in technology-based Science instruction are moderately integrated (Composite Mean = 3.37). The highest-rated indicator is students' motivation and enthusiasm when technology is used (WM = 3.59), followed by increased participation in lessons (WM = 3.46) and improved understanding of concepts through digital tools (WM = 3.41). Mid-ranked indicators include interest in educational apps (WM = 3.38), collaboration through digital platforms (WM = 3.37), access to devices (WM = 3.33), and ability to navigate online platforms (WM = 3.32). The lowest-rated indicators are internet connectivity (WM = 3.30) and completion of digital tasks (WM = 3.29), with another indicator on connectivity ranking last (WM = 3.22). Overall, students show good engagement when technology is used, but limitations in access and connectivity remain.

Section 2: Extent of Students' Learning Manifestation Along 21st Century Skills in Science Table

Table 2.1 Enhancing Critical Thinking Skills

Statements I...	WM	VI	R
1. regularly engage in activities that encourage them to analyze scientific concepts critically	3.51	HM	3
2. promote activities that help students assess information and make informed decisions.	3.37	MM	9
3. encourage students to evaluate and question scientific theories and ideas through discussions and activities.	3.55	HM	1
4. demonstrate the ability to apply scientific principles to real-life problems or scenarios.	3.44	MM	8
5. facilitate learning experiences requiring to identify assumptions and biases in scientific information.	3.51	HM	3
6. encourage to debate and present differing viewpoints on scientific issues in class.	3.35	MM	10
7. integrate critical thinking into most Science lessons through problem-solving exercises and case studies.	3.46	MM	5
8. provide opportunities for students to analyze experimental data and draw logical conclusions based on evidence.	3.53	HM	2
9. actively engage in activities that require them to synthesize information from various sources to solve problems.	3.45	MM	6
10. foster critical thinking through questioning techniques and reflective practices.	3.45	MM	6
Composite Mean	**3.46**	**MM**	

The data show that critical thinking in Science instruction is moderately manifested (Composite Mean = 3.46). The highest-rated indicator is encouraging students to evaluate and question scientific ideas (WM = 3.55), followed by analyzing experimental data and drawing conclusions (WM = 3.53). Other high indicators include engaging students in critical analysis and identifying assumptions and biases (WM = 3.51). Mid-ranked indicators are integration of problem-solving activities (WM = 3.46), synthesizing information and reflective questioning (WM = 3.45), and application to real-life situations (WM = 3.44). The lowest-rated indicators are decision-making activities (WM = 3.37) and encouraging debate and multiple viewpoints (WM = 3.35). Overall, critical thinking is evident but needs strengthening in application, decision-making, and discussion-based strategies.

Section 2: Extent of Students' Learning Manifestation Along 21st Century Skills in Science Table

Table 2.2 Improving Problem Solving Abilities

Statements *I...*	**WM**	**VI**	**R**
1.consistently demonstrate the ability to apply scientific methods to solve problems.	3.47	MM	3
2. provide opportunities for students to engage in hands-on activities that require problem-solving.	3.37	MM	10
3. encourage students to think critically and approach problems from multiple perspectives.	3.53	HM	1
4. frequently involved in group activities where they collaborate to solve complex scientific problems.	3.47	MM	3
5. provide opportunities for students to design and carry out experiments to solve scientific questions.	3.47	MM	3
6. integrate problem solving skills into most Science lessons through real-world scenarios and challenges.	3.41	MM	7
7. am able to break down complex scientific problems into smaller, manageable tasks.	3.45	MM	6
8. encourage to explore multiple solutions and evaluate their effectiveness in solving scientific problems.	3.41	MM	7
9. identify and apply appropriate scientific principles and techniques to solve problems.	3.52	HM	2
10. fosters a problem-solving mindset by encouraging trial and error in experimental processes.	3.41	MM	7
Composite Mean	**3.45**	**MM**	

The data show that problem-solving abilities in Science instruction are moderately manifested (Composite Mean = 3.45). The highest-rated indicator is encouraging students to think critically and use multiple perspectives (WM = 3.53), followed by applying scientific principles and techniques (WM = 3.52). Mid-ranked indicators include application of scientific methods, collaborative problem-solving, and experimental design (WM = 3.47), as well as breaking down complex problems (WM = 3.45). Other indicators such as real-world problem integration, exploring multiple solutions, and trial-and-error approaches obtained (WM = 3.41). The lowest-rated indicator is hands-on problem-solving activities (WM = 3.37). Overall, problem-solving skills are evident but need improvement in practical application and experiential learning.

Section 2: Extent of Students' Learning Manifestation Along 21st Century Skills in Science Table

Table 2.3. Promoting Collaborative Learning

Statements *I…*	WM	VI	R
1. facilitate group discussions where students share ideas and insights during Science lessons.	3.53	HM	1.5
2. design Science activities that require teamwork and cooperative problem-solving.	3.42	MM	8
3. provide opportunities for students to collaborate on designing and conducting experiments.	3.4	MM	10
4. encourage students to take on different roles and responsibilities within their groups.	3.51	HM	4
5. use digital tools or platforms to support collaborative learning in Science.	3.43	MM	7
6. integrate real-world tasks that require joint planning and shared decision-making.	3.46	MM	6
7. promote peer feedback and reflection to improve group performance.	3.53	HM	1.5
8. ensure that collaborative activities align with the lesson objectives and curriculum standards.	3.52	HM	3
9. monitor and guide group interactions to maintain effective collaboration.	3.42	MM	8
10. assess both group outcomes and individual contributions collaborative tasks.	3.49	MM	5
Composite Mean	**3.47**	**MM**	

The data show that collaborative learning in Science instruction is moderately manifested (Composite Mean = 3.47). The highest-rated indicators are facilitating group discussions and promoting peer feedback and reflection (WM = 3.53), followed by alignment of collaborative activities with objectives (WM = 3.52). Mid-ranked indicators include assigning roles in groups (WM = 3.51), assessing group and individual performance (WM = 3.49), and integration of real-world collaborative tasks (WM = 3.46). Other indicators such as use of digital tools (WM = 3.43), teamwork-based activities, and monitoring group interactions (WM = 3.42) are moderately manifested. The lowest-rated indicator is collaboration in designing and conducting experiments (WM = 3.40). Overall, collaborative learning is evident but needs improvement in technology integration and experimental collaboration.

Section 3. Relationship between the Assessment on the Level of Technology Integration and on the Extent of Manifestation of Students Learning Along the 21st century Skills

Table 3.1 Relationship Between the Assessment on The Level Of Technology Integration (Availability Of Digital Tools and Resources) And The Extent of Manifestation on Students Learning

Variables	Pearson's r Value	p-Value	Decision	Remarks
Enhancing Critical Thinking	0.190	0.018	Reject Ho	Significant
Improving Problem Solving Abilities	0.460	0.000	Reject Ho	Significant
Promoting Collaborative Learning	0.380	0.000	Reject Ho	Significant

The data show that the availability of digital tools has a significant positive relationship with students' 21st-century skills. There is a weak but significant correlation with critical thinking (r = 0.190, p = 0.018). A moderate and significant correlation is observed with problem-solving abilities (r = 0.460, p = 0.000) and collaborative learning (r = 0.380, p = 0.000). Overall, digital tools significantly support students' skills, with stronger effects on problem-solving and collaboration than on critical thinking.

Section 3. Relationship between the Assessment on the Level of Technology Integration and on the Extent of Manifestation of Students Learning Along the 21st century Skills

Table 3.2 Relationship between the Assessment on the Level of Technology Integration (Teachers' Digital Literacy and Preparedness) and the Extent of Manifestation on Students Learning

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Variables	Pearson's r Value	p-Value	Decision	Remarks
Enhancing Critical Thinking	0.180	0.023	Reject Ho	Significant
Improving Problem Solving Abilities	0.360	0.000	Reject Ho	Significant
Promoting Collaborative Learning	0.340	0.000	Reject Ho	Significant

The data show that teachers' digital literacy and preparedness have a significant positive relationship with students' 21st-century skills. There is a weak but significant correlation with critical thinking (r = 0.180, p = 0.023). A moderate and significant correlation is observed with problem-solving abilities (r = 0.360, p = 0.000) and collaborative learning (r = 0.340, p = 0.000). Overall, teachers' digital competence plays a meaningful role in enhancing students' problem-solving and collaboration, with a lesser but still significant effect on critical thinking.

Section 3. Relationship between the Assessment on the Level of Technology Integration and on the Extent of Manifestation of Students Learning Along the 21st century Skills

Table 3.3 Relationship between the Assessment on the Level of Technology Integration (Students' Accessibility and Engagement) and the Extent of Manifestation of Students Learning

Variables	Pearson's r Value	p-Value	Decision	Remarks
Enhancing Critical Thinking	0.060	0.426	Failed to Reject Ho	Not Significant
Improving Problem Solving Abilities	0.200	0.011	Reject Ho	Significant
Promoting Collaborative Learning	0.150	0.061	Failed to Reject Ho	Not Significant

Table 3.3 shows that students' accessibility to and engagement with technology have no significant relationship with critical thinking (r = 0.060, p = 0.426) and collaborative learning (r = 0.150, p = 0.061), indicating very weak effects. This suggests that technology access alone does not significantly influence these skills. However, a weak but significant relationship was found with problem-solving skills (r = 0.200, p = 0.011), indicating a slight positive influence of technology engagement on students' ability to solve problems. Overall, the results imply that

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students' access to and engagement with technology have minimal impact on 21st-century skills unless supported by structured instructional strategies and guided use in learning activities.

Section 4. Challenges Encountered by the Teachers in Integrating

The findings identified five key challenges that hinder the effective integration of technology in Science education. First, infrastructure related barriers such as inadequate internet connectivity and limited access to digital devices remain a significant concern, affecting both teaching and learning processes. Second, student accessibility issues persist, particularly in ensuring that all learners have equal opportunities to use digital tools and platforms. Third, the lack of teacher training and ongoing support limits educators' ability to effectively integrate technology into their instructional practices. Fourth, technical glitches and system failures disrupt the continuity of digital learning experiences, reducing instructional time and student engagement. Lastly, varying levels of student digital literacy present challenges in ensuring that all learners can navigate and utilize digital tools effectively.

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Table 4 Challenges Encountered by the Teachers

Sample Participants	Theme	Coded Responses
T1 T2 T3 T6 T7 T8 T9 T10	Infrastructure-related barriers	Poor internet connectivity and unstable signals during lessons. Outdated or insufficient devices such as laptops, projectors, and mobile phones limited the effectiveness of technology integration. Problems with apps, software, and hardware (e.g., HDMI cables, speakers, interactive displays). These interruptions consume valuable class time and reduce instructional effectiveness.
T1 T2 T3 T6 T7 T9 T10	Student accessibility issues	Limited or no internet access at home affected student participation. Not all students owned devices or had consistent access to digital platforms, creating gaps in engagement and learning. Some students rely heavily on prepared materials and struggle with independent use of technology.
T1 T3 T6 T7 T9 T10	Teacher training and support	Trainings were generic and not tailored to Science integration. This limits teachers ability to fully integrate technology into hands-on and computation-based activities.
T2 T 3 T 4 T 8 T 10	Technical glitches and equipment issues	Teachers experienced malfunctions of devices and equipment during class. Teachers noted that certain applications were not suitable for Science computations.
T3 T6 T7	Students' varying digital literacy levels	Students rely heavily on prepared presentations and struggle with independent use of technology

Section 5: Proposed Technology-Based Strategies to Improve Science Instruction

The table below presents the proposed technology-based strategies to address the identified challenges in Science instruction. These include infrastructure enhancement, teacher digital literacy training, student digital inclusion, interactive digital learning, collaborative technology integration, and technical support and maintenance. The strategies aim to improve ICT infrastructure, strengthen teacher capacity in technology integration, and ensure equitable access to digital tools for students. They also promote the use of interactive resources such as

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simulations and virtual labs to enhance conceptual understanding and engagement. In addition, collaborative digital activities are proposed to develop teamwork and problem-solving skills, while technical support systems are included to minimize disruptions during instruction. Overall, the proposed strategies provide a comprehensive approach to improve the effectiveness, accessibility, and sustainability of technology integration in Science education.

Table 5 Proposed Technology-Based Strategies to Improve Science Instruction

Name of Strategy	Description of Strategies	Specific Strategies to Be Done	Objectives	Resources Needed	Expected Outputs/ Outcomes
.Infrastructure Enhancement	Upgrade internet onnectivity and provide ufficient digital devices for tudents and teachers.	Install fiber-optic internet Distribute laptops and tablets Equip classrooms with rojectors and interactive vhite board	Ensure reliable access to igital tools and platforms or effective Science nstruction	High-speed internet, laptops, rojectors, interactive vhiteboards, technical support	mprove access to digital esources, reduced lesson isruptions, enhanced student ngagement
.Teacher Digital Literacy raining	Conduct targeted rofessional development ocused on integrating echnology into Science edagogy	Develop modular training rograms Host webinars and workshop Implement peer mentoring ystems	Equip teachers with skills to ffectively use digital tools n Science nstruction	Training modules, webinars, vorkshops, peer mentoring	ncreased teacher confidence nd competence in using echnology
.Student Digital Inclusion	Provide devices and offline ccess to digital materials or students with limited onnectivity	Launch gadget loan programs Create mobile-Friendly earning platforms	Promote equitable articipation in technology-ased Science activities	Loaner gadgets, mobile-riendly platforms, offline ontent	Greater student participation nd reduced digital divide
.Interactive Digital Learning	Use simulations, virtual abs and multimedia tools o enhance concept elivery and critical hinking	Integrate virtual lab activities Use educational apps and nultimedia Embed simulations in lesson lans	Foster deeper nderstanding nd analytical skills in Science topics	Simulations, Virtual labs, educational apps, nultimedia content	mproved critical thinking and cientific reasoning
.Collaborative Technology ntegration	Design group-based digital ctivities and use latforms that support peer eedback and teamwork	Facilitate group projects via Google Classroom and Zoom Apply digital rubrics for peer ssessment	Enhance collaborative earning and problem-olving skills	Google Classroom, Zoom, Collaborative apps, digital ubrics	Stronger teamwork, ommunication and ngagement in Science task
.Technical Support and Maintenance	Establish support systems o address technical litches and maintain ICT acilities.	Hire dedicated IT personnel Schedule regular naintenance checks Provide troubleshooting guides or teachers	Minimize disruptions and nsure smooth use of echnology in lessons	T personnel maintenance chedules, troubleshooting uides	Reduce technical issues and ninterrupted Science nstructions

Discussion

The findings of the study reveal that technology-based strategies in Science instruction are moderately integrated, and students' 21st-century skills are also moderately manifested. This indicates that while digital tools are present in the teaching and learning process, their full potential in enhancing higher-order thinking skills has not yet been maximized.

The significant relationship between digital tool availability and students' problem-solving and collaborative learning skills supports the idea that access to appropriate technological resources enhances meaningful learning experiences. This finding is consistent with the study of Espinosa et al. (2023), which highlighted that digital tools such as simulations and online laboratories promote analytical thinking and inquiry-based learning. Similarly, Li and Tsai (2020) found that interactive technologies improve students' conceptual understanding and problem-solving strategies.

Moreover, the results show that teachers' digital literacy and preparedness significantly influence students' 21st-century skills, particularly in problem-solving and collaboration. This supports the findings of Abella (2023), which emphasized that teachers' digital competence plays a crucial role in enhancing instructional effectiveness, especially in technology-mediated environments.

In addition, Pizarro et al. (2024) highlighted that teacher with higher levels of digital literacy demonstrate better teaching performance and are more capable of integrating technology effectively in their classrooms. This explains why teacher preparedness emerged as a strong predictor of students' skill development in this study.

Interestingly, the study found that students' accessibility to and engagement with technology have limited influence on critical thinking and collaborative learning. This suggests that access alone does not guarantee improved learning outcomes. This finding is supported by Norris and Soloway (2020), who argued that technology must be accompanied by effective instructional design to produce meaningful learning.

Furthermore, Zhang and Liu (2020) emphasized that technology-assisted collaborative learning is most effective when structured and guided by teachers, reinforcing the idea that pedagogy remains central in technology integration.

The challenges identified in the study, such as poor internet connectivity, limited access to devices, and insufficient teacher training, are consistent with the findings of Bećirović (2023), who identified infrastructure and capacity-building issues as major barriers to effective technology integration in education.

These results imply that improving ICT infrastructure and strengthening teacher professional development are essential to maximizing the benefits of technology in Science education. As emphasized in the literature, successful technology integration requires not only access to digital tools but also competent teachers, institutional support, and well-designed instructional strategies.

However, the study is limited by its reliance on self-reported data and its focus on a single district, which may affect the generalizability of the findings. Future research may explore additional variables such as school leadership, student motivation, and socio-economic factors to provide a more comprehensive understanding of technology integration in education.

Conclusion

Based on the major findings of the study, the researcher drew the following conclusions:

1. The teachers assessed the level of technology-based strategies to be moderately integrated.
2. The assessment of the teachers on the extent of students' learning manifestation was moderately manifested.
3. Significant relationships were found between the level of integration of technology-based strategy and on manifestation of students learning on the availability of digital tools and resources; and in the teachers' digital literacy and preparedness.
4. Teachers face several challenges in integrating technology-based strategies into Science instruction, such as infrastructure limitations, unequal student access, insufficient training, technical disruptions, and varying levels of student digital literacy.
5. The proposed strategies effectively address key barriers in Science instruction by focusing on infrastructure enhancement, teacher digital literacy, and student digital inclusion, aiming to create a more equitable environment. Recommendations engaging technology-integrated learning

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