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Preservice Teachers' Perceptions, Attitudes, and Challenges of Using Scratch as a Coding Tool to Foster Active Learning in Life Sciences Classrooms

Thato Charlot Mashishi and Sam Ramaila*
University of Johannesburg
Johannesburg, South Africa

Abstract. In the contemporary educational landscape, integrating technology into teaching practices is crucial for promoting active engagement and learning, particularly in science classrooms. This study investigated preservice teachers' perceptions of using Scratch as a coding tool to enhance active learning in Life Sciences classrooms. Adopting a qualitative research design, the study used purposive sampling to select five preservice teachers with relevant Life Sciences teaching experience. Data collection involved semi-structured interviews and classroom observations, and thematic analysis was employed to examine the data. The study found that Scratch was perceived positively by preservice teachers as a tool that could foster essential twenty-first-century skills such as collaboration, problem-solving, critical thinking, innovation, and communication. Preservice teachers demonstrated varying levels of familiarity with and adaptability to Scratch, influencing their methods of integration into teaching. While the tool showed promise in engaging students and enhancing active learning, the study also uncovered significant challenges, including resource limitations, inadequate teacher support, and logistical issues such as load shedding. These findings underscore the potential of Scratch to support innovative teaching practices and develop critical skills in learners. However, they also highlight the need for improved resources and support structures to maximise the effectiveness of technology integration. The study offers valuable insights for curriculum developers, higher education institutions, educational communities, and teachers, emphasising the need for strategic interventions to address implementation challenges and optimise the use of Scratch in fostering 4IR skills and preparing students for future careers.

Keywords: scratch; coding; active learning; life sciences education; science; technology; engineering; and mathematics (STEM)

*Corresponding author: Sam Ramaila; *ramailasam8@gmail.com*

1. Introduction

In the contemporary educational landscape, integrating technology into teaching and learning practices has become crucial for fostering active engagement and learning, particularly in science classrooms. With the increasing emphasis on twebnty-first-century skills such as collaboration, problem-solving, critical thinking, innovation, and communication, educators sought effective tools and strategies to enhance student learning experiences. Scratch, a visual programming language developed by the MIT Media Lab, . gained popularity as an accessible and engaging coding tool that could be integrated into various educational contexts. Scratch was a visual programming language and online community primarily designed for children and beginners to introduce them to the basics of programming and computational thinking. Developed by the Lifelong Kindergarten Group at the MIT Media Lab, Scratch enabled users to create interactive stories, games, animations, and simulations by snapping together coding blocks in a drag-and-drop interface. Globally, the era of the Fourth Industrial Revolution (4IR) has brought significant attention to the integration of digital technologies within educational frameworks (Datta, 2023). Coding has emerged as a major topic of interest. Traditionally used in corporate settings for software development, application creation, and data services, coding has become an integral part of educational curricula, especially in Western countries, and is gradually spreading to developing nations (Alt et al., 2020). This shift highlighted the importance of imparting knowledge on how to use coding effectively in teaching and learning (Kwon & Schroderus, 2017).

Many classrooms adopted technological initiatives, incorporating pedagogies like active learning to enhance student engagement and make learning more impactful (Balalle, 2024). Scratch, a user-friendly coding platform, is accessible through applications and digital sites on laptops, tablets, and phones across various operating systems such as iOS, Microsoft, and Android. Coding, as an active learning tool, offers students opportunities to stay motivated and involved in their learning by collaborating, doing and creating (Berssanette & de Francisco, 2021). The incorporation of coding in science classrooms aims to foster active learning by engaging students in diverse activities and tasks designed to facilitate the acquisition of new knowledge and skills in a learner-centred manner (Ogegbo & Ramnarain, 2021). This approach helps students develop relevant twenty-first-century skills and competencies necessary to meet economic and social demands. Therefore, it is imperative for teachers to familiarise themselves with various technological tools compatible with their learners to make science learning more dynamic and effective (Laili & Lufri, 2019).

This study explored the perceptions of preservice teachers regarding the use of Scratch as a coding tool to foster active learning in Life Sciences classrooms. Preservice teachers, who were at the forefront of adopting and experimenting with new pedagogical approaches, provided valuable insights into the practical applications and challenges of using technology in education. By examining their experiences, attitudes and beliefs, this research aimed to shed light on the potential of Scratch to enhance active learning and develop essential skills in Life Sciences education.

2. Background

The integration of technology in education has become increasingly crucial in the contemporary learning environment, where fostering active engagement and the development of twenty-first-century skills are paramount. One of the key technological tools that has emerged is Scratch, a visual programming language developed by the MIT Media Lab. Designed to introduce learners to the basics of programming and computational thinking, Scratch enables users to create interactive stories, games, animations and simulations through a drag-and-drop interface (Aria et al., 2018). Its user-friendly nature makes it accessible for beginners, including young learners and preservice teachers, making it an appealing choice for educational contexts.

In the realm of Life Sciences education, the use of Scratch as a coding tool offers a unique opportunity to enhance active learning. Active learning strategies are characterised by engaging students in activities that promote critical thinking, problem-solving and collaboration (Kim et al., 2013). By incorporating Scratch into Life Sciences lessons, educators can foster a more interactive and participatory learning environment that aligns with the needs of modern learners. Despite the potential benefits, the implementation of Scratch in Life Sciences classrooms presents several challenges. These challenges can include varying levels of familiarity with the tool among teachers, resource constraints and issues related to the integration of technology into existing curricula (Chen & Xiao, 2021). Understanding these challenges and the attitudes of preservice teachers towards Scratch is essential for effectively harnessing its potential to improve teaching and learning outcomes (Zabeli & Gjelaj, 2020).

Preservice teachers, who are in the process of becoming certified educators, play a critical role in the integration of new technologies into classroom practice. Their perceptions and attitudes towards technological tools like Scratch can significantly influence their willingness and ability to incorporate these tools into their teaching practices. Examining how these future educators perceive and interact with Scratch, as well as the challenges they face, provides valuable insights into the practical applications of this tool in real-world educational settings. This study investigates the perceptions, attitudes and challenges faced by preservice teachers in using Scratch as a coding tool to foster active learning in Life Sciences classrooms. By focusing on these aspects, the study aims to contribute to the understanding of how Scratch can be effectively integrated into teaching practices and to identify strategies for overcoming the challenges associated with its use. The findings are intended to inform curriculum developers, teacher educators and policy makers about the effectiveness of Scratch in enhancing educational practices and preparing preservice teachers to integrate technology into their future classrooms.

3. Literature Review

3.1 Conceptualising Scratch as a coding tool in science classrooms

The introduction of new technologies in science classrooms has created various opportunities for integrating innovative pedagogical approaches. According to Yildiz et al. (2020), teachers are now challenged to shift from traditional teaching methods to modern instructional techniques, such as programming and coding. Yükseltürk and Altınok (2015) assert that programming should be taught to schoolchildren to enable them to develop projects and products in future work contexts. Among the various learning programmes available, Scratch has been highly recommended as a visual programming language that can enhance active learning in science classrooms.

Kalelioglu and Gülbahar (2014) describe Scratch as a coding tool that allows users to create interactive stories, games and animations, and to share their work with others in the online community. According to Lamb and Johnson (2011, p. 64), "scratching" in computer software refers to reusable pieces of code that can be easily combined, shared and adapted. Developed at the MIT Media Lab in 2007, Scratch is a free and visually appealing coding platform (Kalelioglu & Gülbahar, 2014). Students can create stories, games, art, music and animations for both fun and academic learning. Consequently, teachers must embrace digital transformation to meet current educational goals.

Scratch coding can be used by teachers across multiple disciplines, including STEM subjects, to engage learners and simplify the abstract concepts within those subjects. As a result, science education has taken steps to introduce Scratch coding in teacher training programmes, enabling teachers to use it during their practice to enhance the quality of science education. However, Ifenthaler and Schweinbenz (2013) argue that for this technological tool to be effective in classrooms, it must be accepted by both teachers and learners. Preservice teachers need to understand how this tool works, its impact on their teaching and learners' understanding, and the importance of not overly relying on this tool for teaching Life Sciences content. A study conducted by Mlambo et al. (2018) suggests that various factors suppress the use of new technologies in teaching and learning, including teachers' personal beliefs, attitudes, and capabilities. Perkmen et al. (2016) further assert that school and classroom environments also influence the use of technology in teaching and learning.

3.2 Perceptions about the use of Scratch as a coding tool for active learning

Due to the rapid technological advancements, teachers need to constantly examine the pedagogic value of using technology in teaching and learning (Kim et al., 2019). Consequently, many education systems have integrated programming and coding into their curricula to foster active learning. According to Wong et al. (2015), the introduction of coding education in many countries' interdisciplinary curricula has expanded, allowing middle school learners to program in a creative context. For instance, in 2011, the South African Department of Education introduced the Curriculum and Assessment Policy Statement, mandating teachers to introduce Scratch to Grade 10 learners as a gateway to learning other programming languages (Marimuthu & Govender, 2018).

In Life Sciences classrooms, coding tools like Scratch are game changers in the twenty-first century because they foster active learning. Preservice teachers are currently being trained to teach Scratch coding and incorporate coding tools into their subject content. However, a study by Altinyelken and Hoeksma (2021) indicated that many Life Sciences classrooms lack active learning components, as most teachers have little knowledge and understanding of learner-centred approaches. Active learning is the process of learning by means of involving the students in some activity that requires them to reflect upon their thoughts and how they are making use of those thoughts (Opdal, 2022). This process can be achieved through the contribution and involvement of both teachers and learners. During this process, teachers' roles shift from delivering knowledge to facilitating and supporting learning, becoming resource persons (González Hernández, 2023). Many studies have supported the notion that Scratch coding can enhance and foster active learning in science classrooms.

Research on the use of Scratch in teaching science concepts reveals varying results and perceptions, both positive and negative (Iyamuremye et al., 2022). These perceptions are influenced by the competencies, skills, and knowledge levels of the teachers. Some teachers may perceive Scratch coding positively but may not feel competent enough to use it effectively. Preservice teachers often lack confidence and feel concerned when they realise that their learners are more technologically proficient and literate than they are (Arvanitis, 2018; Asare & Amo, 2023). Moreover, Mlambo et al. (2018) assert that many teachers believe that using coding tools adds to their workload due to the complexities and changes in the educational landscape. However, other teachers perceive that Scratch coding engages learners, making lessons more enjoyable and active (Liao, 2022). Weintrop (2019) posits that Scratch provides drag-and-drop options, visual cues, and syntax error prevention for first-time programming users. Scratch increases programming and computer achievement and aids in delivering computational thinking (Zhang & Nouri, 2019), and allows learners to develop critical thinking, analytical, collaboration, communication, and problem-solving skills essential for the twenty-first century. Mhlongo et al. (2023) further claim that coding enhances learners' capacity to use technology, aids their learning, and prepares them for various life situations.

Conversely, some studies indicate that preservice teachers view Scratch as a tool that does not significantly enhance programming knowledge or algorithm instruction (Cetin, 2016). Montiel-Cabello and Gomez-Zermeño (2021) believe that Scratch coding lacks advanced features, meaning that as users become more experienced, they may require features like code compilation, options to manage and use single code instances, and version control. Furthermore, a study by Yang and Chen (2023) indicates that some preservice teachers see no benefits in using Scratch coding in science classrooms due to a lack of interest and/or time. This can affect learners' understanding of science concepts and their active engagement in learning.

3.3 Challenges encountered by preservice teachers when using Scratch coding to foster active learning

While Scratch coding offers numerous benefits for fostering active learning, several challenges are associated with its use. One major issue is that teachers often lack a comprehensive understanding of how to integrate Scratch coding with Life Sciences content. Mlambo et al. (2018) further emphasise that some teachers are unaware of the various features available within the tool. Additionally, preservice teachers report a lack of clear guidance in the curriculum on how to effectively use technological tools like Scratch to foster active learning. The curriculum often provides few examples and does not offer practical instructions on integrating Scratch coding into their teaching. Consequently, teachers who have frequently engaged with Scratch coding programs are better positioned to integrate the tool with confidence.

Moreover, there is insufficient support from senior teachers in adopting such technological tools. This lack of support is often due to a lack of understanding and/or interest in technology among trained teachers. Many trained teachers believe they are not skilled or competent enough to use and integrate technological tools in classrooms (Dogan et al., 2021). Additionally, these teachers often express concerns about their imperfect skills and knowledge acquired during and after training. Furthermore, many schools face challenges related to technological infrastructure and financial resources (Mustafa et al., 2024). For instance, there is often a shortage of laptops and tablets necessary for effectively implementing technological tools in classrooms.

3.4 Pedagogical strategies adopted by preservice teachers when using Scratch coding to foster active learning

Modern pedagogical strategies have evolved with the increasing use of technology in education. While research has explored various methods for teaching coding, there is no consensus on the most efficient and effective pedagogical strategies for this purpose (Melro et al., 2023). Many preservice teachers have adopted the strategy of "extreme apprenticeship" when using Scratch coding in their science lessons (Rämö et al., 2019). This strategy also offers teachers the opportunity to practise scaffolding, a technique to support learners in their problem-solving processes.

Another widely adopted strategy is "peer instruction" (Michinov et al., 2015). Dao (2020) highlights peer instruction as a pedagogical approach designed to enhance learner engagement and improve learning outcomes. This strategy has been positively received, with many learners reporting high satisfaction and improvements in their Life Sciences passing rates. Approximately 91% of learners recommend the use of peer instruction in programming or coding classes (Låg & Sæle, 2019). Preservice teachers have also used the strategy of "projected live coding." Rubin (2013) suggests that this approach involves teachers demonstrating coding processes live, rather than relying solely on projected slides. This method can be more effective in promoting active learning by showing learners how to create and debug code in real-time. Additionally, teachers have employed "authentic activities" that relate theory to real-life situations, helping learners to understand Life Sciences content more deeply. Guzdial (2013) found that allowing learners to manipulate images, audio, and video in their early programming assignments enhances retention. Many studies support these pedagogical strategies for their effectiveness in fostering active learning in the classroom.

4. Theoretical Framework

The study is underpinned by the theory of social constructivism, proposed by developmental psychologist Lev Vygotsky. According to Vygotsky (1978), social constructivism is a paradigm that emphasises the importance of culture and interaction in developing cognitive abilities. Social constructivism, as articulated by theorists like Lev Vygotsky, emphasises the role of social interactions and cultural context in the development of cognitive abilities. This theoretical framework is particularly relevant to the study for several reasons. Social constructivism highlights the importance of social interaction in learning. The use of Scratch as a coding tool aligns with this principle by facilitating collaborative learning. Scratch encourages students to work together on coding projects, share their ideas, and solve problems collectively. In the context of preservice teachers, understanding how they perceive and use Scratch can provide insights into how these interactions influence their teaching practices and their ability to foster collaborative learning environments in Life Sciences classrooms.

Vygotsky's (1978) concept of the Zone of Proximal Development (ZPD) emphasises the role of scaffolding in learning. Scratch, as a tool, offers various levels of complexity that can be tailored to the learners' ZPD. Preservice teachers' attitudes and challenges in using Scratch can reflect their experiences with providing appropriate scaffolding to their students. By examining how these teachers integrate Scratch into their lessons, the study explores how they adapt their teaching strategies to support students' development within their ZPD. Social constructivism posits that learners actively construct their own understanding through experiences and interactions. Scratch promotes active learning by allowing students to create, modify and experiment with coding projects. This approach aligns with the constructivist view that knowledge is constructed through active engagement rather than passive reception. The study's focus on preservice teachers' perceptions of using Scratch can reveal how these educators view and implement active learning strategies and how they perceive the impact of Scratch on their students' learning experiences.

Constructivist theory also emphasises the role of cultural and contextual factors in learning. The study's exploration of preservice teachers' experiences with Scratch in Life Sciences classrooms can shed light on how these teachers' cultural and educational backgrounds influence their attitudes and challenges. Understanding these contextual factors can provide valuable insights into how different teaching environments impact the effectiveness of Scratch as a tool for fostering active learning. Incorporating social constructivism into the study allows for a deeper understanding of how preservice teachers' interactions with Scratch influence their pedagogical practices and how they support student learning. It highlights the importance of social interaction, contextual learning and active engagement in the use of technology in education. By analysing these elements, the study can contribute to a broader understanding of how technological tools like Scratch can be effectively integrated into educational practices to enhance active learning and foster deeper understanding in Life Sciences education.

5. Purpose of the Study

The purpose of this study is to explore preservice teachers' perceptions of using Scratch as a coding tool to foster active learning in Life Sciences classrooms. Specifically, the study aims to:

- Examine preservice teachers' perceptions, attitudes, and challenges related to the use of Scratch in Life Sciences education.
- Identify the pedagogical strategies adopted by preservice teachers when integrating Scratch coding into their teaching practices to enhance active learning.

By achieving these objectives, the study aims to contribute to the existing body of research on technology integration in education and to enhance the preparation of future teachers for using digital tools to create engaging and effective learning environments.

6. Methods

6.1 Research paradigm

The study is grounded in the interpretivist or constructivist paradigm. The interpretivist paradigm allows for an exploration of how individuals perceive and make sense of the world (Frechette et al., 2020). This paradigm emphasises understanding the epistemology of knowledge, where data is interpreted, and meanings are constructed. It enables an understanding of knowledge and reality as well-constructed data derived from communication, collaboration, interaction, and practice. Before implementing technological approaches and strategies in classrooms, it is crucial to understand why these approaches are perceived as either ideal or non-ideal. The interpretivist framework facilitates this understanding by analysing student teachers' perspectives and uncovering the underlying reasons for their views on integrating coding techniques in Life Sciences classrooms. This approach helps in fostering authentic learning by aligning with the teachers' interpretations and experiences.

6.2 Research methodology

This study employed a qualitative methodology to address the research questions, offering deeper insights into preservice teachers' perceptions regarding the use of Scratch as a coding tool to foster active learning in Life Sciences classrooms. A qualitative methodology is well-suited to answer the research questions, expanding on ideas and providing opportunities to explore open-ended questions (Tomaszewski et al., 2020). This approach allowed for a comprehensive exploration and explanation of how different respondents perceived and interpreted various aspects of using Scratch coding. Creswell and Guetterman (2019) asserted that qualitative methods generated rich descriptions of participants' perceptions and thought processes, enabling a focus on the reasons behind why a particular phenomenon was perceived or occurred. This methodology facilitated accurate reporting on participants' experiences, attitudes, and behaviours, explaining their thoughts and feelings during the relevant events. Additionally, qualitative methodology helped in understanding the extent to which preservice teachers felt confident in using Scratch coding in their Life Sciences lessons. It allowed for an in-depth examination of the pedagogical strategies they employed with the coding tool and provided insights into their experiences and perceptions. This approach also identified the opportunities for implementing coding that preservice teachers had learned from their training.

6.3 Research design

This study uses a case study research design. This design is centred on an in-depth exploration and understanding of a specific phenomenon within its real-life context (Creswell & Creswell, 2018). According to Priya (2021), the case study design involves an intensive examination of a single case or a small number of cases over an extended period. It aims to provide detailed and comprehensive insights into the complexities and nuances of the phenomenon being studied. This approach facilitates interaction with multiple preservice teachers, allowing for a thorough investigation of their experiences and perceptions regarding the use of Scratch coding in Life Sciences classrooms.

6.4 Participants and sampling procedure

The participants consisted of two groups: two 3rd-year students and three 4th-year undergraduate students, all enrolled in the education programme for the Senior and Further Education and Training phases. In the South African context, the Senior Phase includes Grade 7 to Grade 9, and the FET Phase covers Grade 10 to Grade 12. The selection of participants was based on their subject specialisation in Life Sciences and their involvement in the Scratch coding programme within the Faculty of Education. All participants also had experience in teaching Life Sciences, including practical components of Work Integrated Learning. A purposive sampling strategy was employed to identify participants who had specifically majored in and taught Life Sciences and who had completed the Scratch coding program. This approach was necessary because, although many students from the Faculty of Education had participated in the Scratch program, the sample did not include those pursuing foundation and intermediate teaching qualifications, as their specialisations differed. The sampling strategy aimed to select six participants who had practical experience with Scratch coding in educational settings. The final sample size was determined based on data saturation, ensuring that sufficient data had been collected to draw comprehensive conclusions and provide detailed insights.

6.5 Data collection procedures

Data was collected through two primary tools: observations and interviews. The aim was to gain a comprehensive understanding of how preservice teachers used Scratch coding methods and their perceptions of this tool in their Life Sciences classrooms.

Observations:

A participatory observation approach was employed, where the researchers engaged in the research as participant observers. Dennis (2014) highlights that this method provides an inside view of respondents' authentic interactions and behaviours within the specific setting. During the observations, checklists were used to systematically document key aspects of the classroom environment and teacher-student interactions. These checklists included items such as:

- Teacher's use of Scratch coding: Whether the teacher used Scratch during the lesson, how it was integrated, and its effectiveness.

- Student engagement: How students interacted with Scratch and their level of engagement with the coding activities.
- Pedagogical strategies: Techniques employed by the teacher to facilitate learning through Scratch.
- Challenges observed: Any difficulties or issues encountered during the use of Scratch in the classroom.

Detailed notes were taken to capture relevant events and dynamics, including observations of teacher-student interactions and the overall classroom atmosphere.

Observing Attitudes:
Observing attitudes was a critical component of the study to understand how preservice teachers' perceptions and feelings towards using Scratch as a coding tool influenced their teaching practices and interactions with students. Attitudes encompass beliefs, motivations, and overall enthusiasm toward the integration of Scratch, which can significantly impact its effectiveness in fostering active learning. To capture and analyse attitudes, the observation focused on several key areas:

Teacher Enthusiasm and Motivation: Observations aimed to assess the level of enthusiasm and motivation that preservice teachers displayed towards using Scratch. Indicators included their verbal expressions of excitement, the energy they brought to their lessons, and their proactive engagement with the coding tool.

Instructional Practices and Attitude Reflection: Teachers' instructional practices were observed to determine how their attitudes toward Scratch influenced their teaching methods. For instance, were they incorporating Scratch creatively into their lessons? Did they encourage active participation and exploration among students?

Student Reactions and Engagement: Observing student reactions and engagement provided indirect insights into teachers' attitudes. High levels of student interest and participation often reflected positively on the teachers' attitudes and their effective use of Scratch.

Data Collection Procedures:
a. Participatory Observation: The researchers conducted participatory observations to immerse themselves in the classroom environment, providing a first-hand view of how attitudes were manifested in real-time interactions. This involved:

Lesson Observations: Five lesson observations were conducted, with each preservice teacher being observed once. Detailed notes were taken on how teachers' attitudes were reflected in their teaching practices, interactions with students and use of Scratch.

Behavioural Indicators: Specific behavioural indicators were noted, such as the frequency of positive reinforcement, encouragement of student creativity, and responsiveness to student questions or difficulties.

b. Reformed Teaching Observation Protocol (RTOP): The RTOP was employed to systematically assess the quality of teaching and engagement. While primarily used to evaluate teaching effectiveness, RTOP also provides insights into teachers' attitudes by highlighting how they engage students and manage the classroom.

Interviews:
Two sets of interviews were conducted to provide a comprehensive understanding of preservice teachers' perceptions of using Scratch coding in their classrooms. The interviews targeted undergraduate Life Sciences preservice students.

Number of items: Each interview consisted of 10-15 open-ended questions designed to explore various aspects of their experiences with Scratch.

Types of interview questions:

- Perceptions and attitudes: Questions aimed to explore preservice teachers' overall views on using Scratch, their attitudes toward its effectiveness, and how they felt it impacted their teaching practices. Example: "How do you perceive the effectiveness of Scratch coding in enhancing active learning in your Life Sciences classes?"
- Integration and application: Questions focused on how preservice teachers integrated Scratch into their lessons, the strategies they employed, and any adjustments made. Example: "Can you describe how you integrated Scratch into a recent Life Sciences lesson? What strategies did you use?"
- Challenges and support: Questions sought to identify any challenges faced during implementation and the support they received or needed. Example: "What challenges did you encounter when using Scratch in your classroom, and what support would have been beneficial?"
- Skills and development: Questions explored how the use of Scratch contributed to developing twenty-first-century skills and any insights gained from their training. Example: "In what ways has using Scratch coding helped you develop skills related to the Fourth Industrial Revolution (4IR) in your teaching practice?"

The interviews aimed to capture a range of experiences and insights, providing a rich, qualitative understanding of the preservice teachers' interactions with Scratch coding and its impact on their teaching and learning.

6.6 Data Analysis
The data collected from the interviews were analysed using qualitative coding techniques to identify patterns, codes, themes, and meanings. An inductive approach was employed for data analysis, allowing the exploration of data without preconceived notions, which facilitated the discovery of new patterns, themes and relationships not previously considered. Additionally, Otter.AI was used to transcribe the interviews, aiding in the identification and examination of interrelationships among codes and themes.

To analyse the data collected from observations, we began by meticulously transcribing the detailed notes and checklist data recorded during the classroom sessions. These notes provided a rich account of teacher-student interactions, the application of Scratch coding, and the overall classroom dynamics. The transcribed data was organised into various categories to facilitate a structured analysis. Categories included aspects such as "Teacher's Use of Scratch," "Student Engagement," "Pedagogical Strategies," and "Challenges." Each observation session was scrutinised to identify key themes and patterns within these categories. Initial coding involved creating a set of preliminary codes that represented recurring concepts and observations. For example, codes like "Effective Use of Scratch" and "Student Participation" were used to mark significant events and interactions observed in the classroom. As the analysis progressed, these codes were refined and grouped into broader thematic categories, reflecting consistent patterns and notable deviations across different observation sessions.

The next step involved identifying patterns and trends within the data. By examining how Scratch coding was applied across various lessons, we observed recurring techniques and strategies used by teachers, as well as patterns in student engagement. For instance, certain pedagogical strategies consistently led to higher levels of student interaction, while specific challenges were frequently encountered. Cross-analysis was employed to compare observations from different sessions. This comparative analysis highlighted variations in how Scratch was implemented and its impact on learning outcomes. It also allowed us to discern consistent themes related to the effectiveness of Scratch coding, the nature of student engagement, and the challenges faced by teachers. Interpreting the findings involved contextualising the observed behaviours and interactions within the classroom setting. We examined how the use of Scratch aligned with instructional goals and the broader educational context. Linking the observations to these theoretical frameworks provided deeper insights into how Scratch coding supported or hindered active learning. For example, we explored how the integration of Scratch facilitated formative assessment and encouraged self-regulation among students.

To ensure the accuracy and reliability of our findings, we employed triangulation by comparing observational data with responses from interviews and other data sources. This cross-validation confirmed the consistency of our observations and interpretations. Peer review was also used to gather feedback from colleagues, which further ensured the credibility of the analysis. The final stage involved summarising the key findings, presenting a descriptive analysis of how Scratch was used in teaching, and detailing its effects on student engagement and learning outcomes. The analysis provided valuable insights into the practical application of Scratch coding in Life Sciences classrooms, highlighting both the benefits and challenges encountered by preservice teachers. These insights contributed to a deeper understanding of how technology can enhance active learning and support the development of twenty-first-century skills in educational settings.

6.7 Ethical considerations

The Research Ethics Committee at the institution where the study was conducted granted ethical clearance (Sem-2020-031). The research procedures were thoroughly explained to the participants, who voluntarily agreed to take part. To ensure anonymity and confidentiality, pseudonyms were used. Informed consent was obtained from all participants, who were also informed that they could withdraw from the study at any time without facing any consequences.

7. Findings

As previously described, data were collected from five teacher candidates, who were assigned pseudonyms 'T1, T2, T3, T4, T5'. These candidates were observed while using Scratch coding in their Life Sciences classrooms and were interviewed by the researchers for approximately 30-40 minutes each. This contributed to the research instruments used in the study. Themes were derived from the data collected through both the interviews and the observation schedule. Specifically, themes emerged from the interview questions and the observation notes, providing a comprehensive analysis of the participants' experiences and perceptions.

7.1 Findings emanating from observational data

Conducting observations initially provided a comprehensive and objective view of the use of Scratch in Life Sciences classrooms. This approach established a clear context for the study, informed the development of relevant interview questions, and allowed for a thorough analysis of teacher and learner interactions. By capturing real-time data on pedagogical practices and challenges, the observations laid a solid foundation for deeper exploration and understanding through subsequent interviews. Based on the observational data, three primary themes emerged from the analysis of preservice teachers' use of Scratch coding in Life Sciences classrooms. These themes highlight key aspects of the integration of technology into teaching practices, including engagement with the tool, interactions with learners, and attitudes towards using Scratch.

A. Teachers' Engagement with Scratch Coding Tool

Description: The observations revealed varying levels of engagement with Scratch among the preservice teachers. Teachers demonstrated different degrees of familiarity and proficiency with the coding tool, which influenced their interactions and effectiveness in using Scratch in their lessons.

Findings:

High Engagement: T1 and T4 showed strong engagement with Scratch, integrating it effectively into their teaching practices. They utilised the tool to enhance student participation and active learning, demonstrating a high level of comfort and knowledge about Scratch.

Moderate Engagement: T2, T3, and T5 exhibited moderate engagement, with T2 showing the highest familiarity and confidence. However, their effectiveness in leveraging Scratch varied, reflecting their differing levels of training and experience with the tool.

Correlation with Learner Participation: The observations indicated that higher teacher engagement with Scratch was associated with increased student involvement and active learning during lessons.

Implication: Teachers' familiarity and active use of Scratch play a crucial role in enhancing the learning experience, suggesting that targeted training and support for preservice teachers could improve their engagement and effectiveness.

B. Teacher-Learner Interactions

Description: The nature of interactions between teachers and learners was a critical aspect of how Scratch was used in the classroom. The observations focused on how teachers facilitated student learning and engagement through the use of Scratch coding.

Findings:

Effective Interaction: T2 and T4 demonstrated more effective interactions with students, employing strategies that placed learners at the centre of their learning. They used group work, student-led demonstrations, and discussions to engage students actively.

Intermediate Interaction: Three out of five teachers scored at an intermediate level of interaction. They balanced their attention between student engagement and managing the technical aspects of Scratch.

Facilitation of Learning: Teachers generally facilitated learning by guiding students through errors and acknowledging their correct actions, fostering an environment conducive to active participation.

Implication: Effective teacher-student interactions, facilitated using Scratch, are essential for promoting active learning and student engagement. Teachers who adopt interactive and student-centred approaches can enhance the learning experience.

C. Teachers' Attitudes and Perceptions

Description: Teachers' attitudes towards Scratch and their perceptions of its effectiveness in promoting active learning were explored. These attitudes were crucial in determining how well the tool was integrated into their teaching practices.

Findings:

Positive Attitudes: Teachers exhibited significant interest, motivation, and enthusiasm for using Scratch. Their positive attitudes towards the tool and its potential for active learning were evident.

Impact on Pedagogical Practices: The teachers' positive perceptions contributed to their willingness to adopt Scratch in their lessons, reflecting an agreement on the tool's effectiveness in enhancing pedagogical practices and student engagement.

Attitudinal Influence: The enthusiasm and confidence of teachers in using Scratch were associated with higher levels of engagement and better implementation of the tool in their teaching.

Implication: Teachers' positive attitudes and perceptions towards Scratch can significantly influence their teaching practices and the successful integration of the tool into the classroom. Supporting and reinforcing positive attitudes towards educational technology can enhance its adoption and effectiveness.

These themes provide valuable insights into the integration of Scratch coding in Life Sciences education and highlight areas for further development and support for preservice teachers.

7.2 Findings from interview data

All interviews were conducted after observing five lessons led by preservice teachers with pseudonyms T1, T2, T3, T4, and T5. These interviews were scheduled at times convenient for the participants and were conducted using the Zoom online platform. The interviews aimed to align with the observations, allowing for a comparison between the teachers' opinions and their practical experiences using Scratch in Life Sciences classrooms to foster active learning.

A. Preservice teachers' acceptance and adaptability of using Scratch as coding tool

Many teachers demonstrated acceptance and adaptability toward using Scratch coding, recognising its potential effectiveness and the ways it can engage learners. Data collected from interviews revealed that teachers perceived Scratch coding as an effective tool for teaching Life Sciences. All five teacher candidates agreed that Scratch is highly effective, describing it as a wonderful and user-friendly tool. They noted that Scratch enhances active learning by requiring students to be actively involved and engaged in their own learning. Additionally, they highlighted that Scratch stimulates twenty-first-century skills, such as collaboration, critical thinking, communication, and creativity. Maloney, Resnick, Rusk, Silverman, and Eastmond (2010) support these views, noting that Scratch's primary goal is to facilitate efficient and self-directed learning through experimentation and collaboration with peers.

However, T3 noted that while Scratch is effective, it should not be the sole or primary tool in teaching; rather, it serves as a supportive tool. Despite this, all participants expressed a positive attitude towards using Scratch in their Life Sciences classrooms. Their enthusiasm is reflected in their feedback:

> **T1**: "Learner engagement is coupled with the understanding of using Scratch to learn. Those who understand it are likely to be invested in the topic being taught and enjoy learning, but those who do not have a lower engagement."
>
> **T2**: "When I use traditional teaching methods, learner engagement is not as high. However, with Scratch, engagement increases significantly because students can be creative and think critically while enjoying the process."
>
> **T3**: "Learners participate eagerly because they find it fun."
>
> **T4**: "Learner engagement is extremely high."
>
> **T5**: "Learners are always hands-on and minds-on."

These responses indicate that teachers are positive about using Scratch, as supported by the learners' willingness and interest in coding and learning science concepts through the tool. The high levels of participation reported by the teachers suggest that incorporating Scratch into teaching enhances student motivation and learning experiences. Furthermore, two out of the three participants emphasised that using Scratch helps develop essential twenty-first-century skills. Scratch aids in developing computational thinking and crucial skills like critical thinking, analytical abilities, collaboration, communication, and problem-solving, which are vital for the twenty-first century (Wu et al., 2024).

B. Teachers' Prior Experiences with Using Coding Tools for Teaching and Learning

Teachers' prior experiences with coding tools vary significantly, influencing their approach to using Scratch coding and other platforms like JavaScript, Code Academy, and HTML. Proficiency with digital tools often stems from prior exposure and the ability to apply those skills to new, more sophisticated tools with advanced features and interfaces (Livingstone et al., 2023). Some teachers drew on previous facilitation and training experiences, while others had no prior coding experience before engaging with the Scratch programme, as reflected in the following excerpts:

> **T1**: "I did not have prior experience with Scratch. I attended courses related to Python, which I was introduced to by a friend/roommate."
>
> **T2**: "I had experience with HTML during my university years in a module during COVID-19."
>
> **T3**: "Unfortunately, I haven't been exposed to different platforms except for my recent involvement with the Scratch programme."
>
> **T4**: "I haven't been exposed to different coding tools."

These responses indicate that some teachers have a background in coding and programming, either through formal education or personal interest, while others have very limited or no prior coding experience. Despite this, teachers with no prior coding experience were not discouraged but expressed a willingness to learn more, showing adaptability to using Scratch. Scratch is designed to introduce programming to individuals with no prior experience, offering a valuable learning opportunity for beginners (Campbell & Atagana, 2022). Conversely, teachers with experience in other coding tools also showed interest in using Scratch to teach Life Sciences concepts. Their prior experience provided an advantage, strengthening their perceptions of and consistency in using Scratch, as it complemented their existing skills and enhanced their overall attitude toward using various coding tools.

C. Challenges encountered by preservice teachers when using Scratch as a coding tool in Life Sciences classrooms

Teachers with prior experience in Scratch and other coding tools reported encountering various challenges while using Scratch coding. These challenges included a lack of support and contextual factors. Many teachers in schools do not provide adequate support for preservice teachers in using technology in classrooms, which hampers the effective implementation of these tools. This issue is echoed in T5's response during the interview about the challenges faced when using Scratch coding in Life Sciences classrooms:

> **T5**: "I'd also say that in-service teachers fail to support us in incorporating the tools because most of them are not knowledgeable about the tools."

This lack of support influences learners' motivation, as it reflects poorly on teachers, who may be perceived as incompetent with technology (Johnson et al., 2016). Furthermore, teachers noted that load shedding significantly affects the successful implementation of Scratch. As a national crisis, load shedding disrupts electricity supply, which in turn affects teaching. Without electricity, teachers are forced to revert to traditional teaching methods and improvise. Internet connectivity is often disrupted during power outages, as most schools' Wi-Fi or personal data relies heavily on electricity. Additionally, the limited understanding of technology among trained teachers makes it difficult for them to address technical issues such as internet connectivity problems and gadget malfunctions. For example, T1 described experiencing connectivity issues when using Scratch coding due to the school's intermittent connection.

D. Pedagogical strategies adopted by preservice teachers when integrating Scratch coding into their teaching practices to enhance active learning

The interview responses corroborated the observations regarding the use of the Scratch coding tool in teaching Life Sciences. The feedback revealed that while some teachers had employed Scratch for assessment purposes, others had not. It was noted that some teachers were still becoming familiar with the tool, with one teacher indicating an intermediate level of familiarity. For those who did use Scratch for assessments, informal methods such as quizzes, multiple-choice questions, and true/false questions were commonly used. The interviewees discussed their pedagogical practices and preferences related to Scratch features. The responses highlighted various teaching strategies, all aimed at fostering collaboration and communication among students. Every participant used collaborative methods to enhance students' understanding of Life Sciences concepts and to contextualise real-world experiences within the classroom environment. T1, T2, and T3 emphasised their preference for using group work, class discussions, and storytelling. T2 explained that he organised students into groups of three or four, assigning tasks based on their birthdays. This approach aimed to engage students more deeply with the content. The analysis of interview data confirmed a shared belief among teachers that using Scratch coding tools facilitates a better understanding of concepts. T4 illustrated this by stating:

> "I want you (learners) to create a story using the topic of environmental studies."

This strategy allowed learners to grasp the concept more effectively by creating a project on Scratch related to their subject matter.

8. Discussion of Findings

This study explored preservice teachers' perceptions, attitudes, and challenges associated with using Scratch as a coding tool to foster active learning in Life Sciences classrooms. The findings, derived from observations and interviews, offer valuable insights into how Scratch is integrated into teaching practices and the broader implications for active learning and pedagogy. The study revealed that preservice teachers generally had positive perceptions of Scratch as a coding tool. They viewed it as an engaging and versatile resource that could enhance active learning in Life Sciences. The positive perception aligns with existing literature highlighting Scratch's effectiveness in making learning interactive and dynamic (Welbers et al., 2019; Zainuddin et al., 2020). Teachers appreciated Scratch's user-friendly interface and its ability to facilitate creative expression and problem-solving among students.

Despite the overall positive perception, there was variability in how teachers engaged with Scratch. Teachers who demonstrated a higher level of familiarity with the tool showed greater enthusiasm and more innovative uses of Scratch in their lessons. For example, T1 and T4 used Scratch extensively to create interactive simulations and visualisations, which significantly enhanced student engagement. In contrast, teachers with less experience, such as T2 and T3, exhibited a more conservative approach, limiting their use to basic functions. This variability underscores the importance of comprehensive training and continuous support to maximise the potential of Scratch in educational settings. Preservice teachers displayed considerable enthusiasm and motivation for integrating Scratch into their teaching. Their positive attitudes were reflected in their lesson delivery and interactions with students. Teachers like T2 and T4, who actively engaged students through group work and interactive activities, illustrated how a positive attitude towards Scratch can foster a collaborative learning environment. This finding supports the notion that teachers' attitudes towards technology can influence their pedagogical practices and effectiveness (Eickelmann & Vennemann, 2017; Wijnen et al., 2021). Furthermore, the study found that teachers' attitudes towards Scratch were closely linked to their pedagogical practices. Those with a positive outlook were more likely to incorporate Scratch creatively and adaptively into their teaching, enhancing student engagement and learning outcomes. This was evident in the use of collaborative projects and student-led demonstrations, which were more prevalent among teachers who expressed a strong commitment to using Scratch. This correlation highlights the need for fostering a positive attitude towards educational technologies to achieve better pedagogical results.

The study identified several challenges faced by preservice teachers when using Scratch, including technical issues and limited resources. Teachers reported problems such as connectivity issues, insufficient hardware, and power outages. For instance, T4 struggled with connectivity problems that disrupted the lesson flow, while T5 faced interruptions due to load shedding. These challenges reflect broader infrastructural issues that can impact the effective use of technology in education. Addressing these barriers is crucial for ensuring that all teachers can effectively leverage digital tools like Scratch. Another significant challenge was the varying levels of familiarity and expertise with Scratch among preservice teachers. Teachers with less experience often struggled with integrating Scratch into their lessons, indicating a need for more robust training and ongoing professional development. This finding suggests that effective use of Scratch requires not only initial training but also continuous support to help teachers overcome challenges and fully utilise the tool's capabilities.

The findings underscore the importance of targeted professional development programmes to equip preservice teachers with the necessary skills and confidence to use Scratch effectively (Simonsen et al., 2020). Training should focus on both technical proficiency and pedagogical strategies to ensure that teachers can integrate Scratch seamlessly into their teaching practices. To address technical and resource-related challenges, schools and educational institutions need to provide better infrastructure and support. This includes ensuring reliable internet access, sufficient hardware, and contingency plans for power outages. By addressing these issues, educational settings can create a more conducive environment for using technology like Scratch.

Future research should explore the long-term impact of using Scratch on student learning outcomes and engagement. Additionally, examining the effects of different training models on preservice teachers' ability to use Scratch could provide valuable insights into how to improve professional development programmes. This discussion highlights the multifaceted nature of integrating Scratch into Life Sciences education, emphasising the need for positive attitudes, effective training, and addressing challenges to enhance the use of coding tools in fostering active learning.

9. Implications for Pedagogic Innovation

The study reveals several significant implications for pedagogic innovation. These insights underscore how Scratch coding can reshape teaching practices and enhance learning experiences in Life Sciences classrooms. The study highlights the diverse experiences and perceptions of preservice teachers regarding Scratch coding. To optimise the integration of such tools, teacher preparation programmes should emphasise the importance of technological proficiency. This includes not only training teachers to use tools like Scratch effectively but also equipping them with strategies to adapt these tools to various educational contexts. By incorporating coding tools into teacher training, programmes can better prepare educators to leverage technology in ways that enhance student engagement and learning outcomes. The findings reveal that Scratch coding fosters active learning by engaging students in hands-on, creative tasks. This suggests that educators should incorporate more active learning strategies in their teaching methods. By using coding tools to facilitate project-based learning, collaborative tasks, and real-world problem-solving scenarios, teachers can create more dynamic and interactive learning environments. The emphasis should be on creating opportunities for students to explore, experiment, and apply their knowledge in practical contexts.

The study demonstrates that collaborative methods, such as group work and class discussions, are effectively used alongside Scratch coding to enhance understanding. This indicates a need for pedagogical practices that prioritise collaboration and communication. Educators should consider integrating collaborative projects and peer-to-peer interactions into their curricula, encouraging students to work together to solve problems and share their findings. This approach not only improves comprehension but also develops essential twenty-first-century skills like teamwork and communication. The challenges faced by teachers, such as connectivity issues and lack of support, underscore the necessity for schools to provide adequate technological infrastructure and support. For Scratch coding and similar tools to be effectively integrated, schools must address these barriers by ensuring reliable internet access, sufficient hardware, and ongoing technical support. Educators should also be supported by in-service training and professional development to navigate these challenges and maximise the benefits of technology in their teaching practices.

The study reveals varying levels of prior experience with coding tools among preservice teachers. To address this, professional development programmes should cater for diverse technological backgrounds, offering foundational training for those new to coding and advanced workshops for more experienced educators. Tailoring support to individual needs can enhance teachers' confidence and competence in using coding tools, ultimately benefiting student learning. The positive attitudes of preservice teachers towards Scratch coding, despite the challenges, highlight the potential for ongoing improvement in pedagogical practices. Educators should be encouraged to reflect on their use of technology, seek feedback, and engage in continuous professional development. By fostering a culture of continuous improvement, teachers can stay updated on best practices and emerging technologies, ensuring that their pedagogical approaches remain effective and relevant.

In summary, the study's implications for pedagogic innovation emphasise the need for a holistic approach to integrating technology in education. By enhancing teacher preparation, promoting active and collaborative learning, addressing technological challenges, supporting diverse backgrounds, and fostering continuous improvement, educators can leverage tools like Scratch coding to create more engaging and effective learning experiences in Life Sciences classrooms.

10. Limitations

The findings of this study are based on a small sample size of five preservice teachers. While this sample provides valuable insights into their experiences and perceptions, the results may not be generalisable to a broader population of preservice teachers or different educational contexts. The specific characteristics of the sample, including their training background and experiences with Scratch, may influence the findings and limit their applicability to other settings or groups. The study focused exclusively on preservice teachers engaged in a Work Integrated Learning and Service-Learning programme. This population may not fully represent the broader range of preservice teachers across different programmes or institutions. Consequently, the perceptions, attitudes, and challenges identified may differ from those of preservice teachers in other contexts or at different stages of their training.

The study used a purposive sampling technique to select participants who had experience with Scratch coding. While this approach ensured that participants had relevant experience with the tool, it also introduced potential biases. The selection process may have favoured individuals who were more familiar or comfortable with technology, thus not capturing the perspectives of those less experienced or less confident in using coding tools. The study employed qualitative methods, including observations and interviews, to explore preservice teachers' perceptions and experiences. While qualitative methods provide in-depth insights, they also have limitations in terms of subjectivity and researcher interpretation. The observational data were subject to the researchers' interpretations, which may introduce biases. Additionally, the study's reliance on self-reported data from interviews may not fully capture the complexity of participants' experiences or the nuances of their interactions with Scratch. The study was conducted during a specific timeframe within the Work Integrated Learning and Service-Learning programme, which may affect the relevance of the findings to other periods or educational contexts. Factors such as the timing of observations, the specific educational setting, and external influences like technological issues or institutional support may have impacted the results.

In summary, while the study provides valuable insights into preservice teachers' perceptions of using Scratch in Life Sciences classrooms, these limitations should be considered when interpreting the findings and applying them to other contexts. Future research could address these limitations by expanding the sample size, using diverse sampling techniques, and exploring the experiences of preservice teachers in various settings.

11. Conclusion

This study explored preservice teachers' perceptions, attitudes and challenges associated with using Scratch as a coding tool to foster active learning in Life Sciences classrooms. The findings revealed that preservice teachers largely viewed Scratch as an effective and engaging tool for enhancing student learning. They appreciated Scratch's interactive features, which facilitated hands-on activities, promoted creativity, and deepened students' understanding of Life Sciences concepts. Preservice teachers employed a variety of pedagogical strategies with Scratch, including group work, class discussions, and storytelling, to support active learning and improve student collaboration and communication. These strategies were found to bolster critical thinking and problem-solving skills while contextualising Life Sciences concepts within real-world scenarios.

However, the study also identified several challenges faced by preservice teachers, such as technological limitations, inadequate institutional support, and disruptions from load shedding. These issues impacted the effective implementation of Scratch coding and highlighted the need for improved technological infrastructure and support systems. Despite these challenges, preservice teachers generally demonstrated a positive attitude towards using Scratch and recognised its potential benefits. The study concludes that Scratch coding holds significant promise for enhancing teaching and learning in Life

Sciences classrooms. To fully realise its potential, it is crucial to address the challenges associated with technology integration and provide ongoing professional development and support for educators. By leveraging Scratch effectively, educators can create a more dynamic and interactive learning environment that better prepares students for the demands of the twenty-first century.

12. Recommendations

Based on the findings of the study on preservice teachers' perceptions, attitudes, and challenges related to using Scratch as a coding tool in Life Sciences classrooms, several recommendations are proposed to enhance the integration of Scratch and support effective teaching practices:

Enhanced Professional Development: To address variability in proficiency with Scratch, targeted professional development programmes should be implemented. These programmes should focus on equipping preservice teachers with comprehensive training in Scratch coding and pedagogical strategies for its effective use in the classroom. Workshops and ongoing support could help bridge gaps in experience and ensure all educators can harness Scratch’s full potential.

Strengthening Technological Infrastructure: Given the challenges posed by technological limitations and connectivity issues, it is essential to invest in improving technological infrastructure in educational settings. Schools and educational institutions should prioritise upgrading hardware, ensuring reliable internet access, and providing technical support to facilitate seamless implementation of coding tools like Scratch.

Institutional Support: Institutions should offer more robust support for preservice teachers by integrating Scratch coding into the curriculum and providing resources such as lesson plans, teaching aids, and access to coding platforms. Creating a supportive environment where preservice teachers can collaborate and share best practices would also enhance the overall effectiveness of using Scratch.

Addressing Load Shedding Impacts: To mitigate the effects of load shedding and other interruptions, schools should explore alternative solutions such as offline coding activities, backup power sources and flexible scheduling. Developing contingency plans can help ensure that teaching with Scratch remains consistent and effective despite external challenges.

Promoting Collaboration and Sharing: Encouraging preservice teachers to collaborate and share their experiences with Scratch can foster a community of practice. Platforms for sharing lesson plans, coding projects, and teaching strategies can provide valuable insights and support, helping educators to learn from one another and continuously improve their use of Scratch.

Continuous Evaluation and Feedback: Implementing a system for continuous evaluation and feedback on the use of Scratch in classrooms can help identify and address issues in real-time. Regular assessments of how Scratch is being used and its impact on student learning will provide insights into areas for improvement and ensure that the tool is effectively meeting educational goals. By addressing these recommendations, educational institutions can better support preservice teachers in using Scratch as a powerful tool for fostering active learning in Life Sciences classrooms. This approach will enhance teaching practices, improve student engagement, and contribute to the development of a more interactive and effective learning environment.

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