The Role of Technology Integration in the Development of 21st Century Skills and Competencies in Life Sciences Teaching and Learning

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Abstract

Development of 21st century skills and competencies in teaching and learning remains a key strategic imperative. Coherent development of skills and competencies requires adoption of innovative pedagogical strategies. Technology integration can be harnessed to foster effective teaching and learning. The study examined the role of technology integration in the development of 21st century skills and competencies in Life Sciences teaching and learning. The empirical investigation adopted an explanatory sequential mixed method design and involved 15 purposively selected teachers from five South African suburban schools. The study is underpinned by social constructivism as the underlying theoretical framework. Quantitative data was collected through the administration of a survey questionnaire with the participants while qualitative data was collected through semi-structured interviews. Technology integration was perceived to promote the acquisition of 21st century skills and competencies in Life Sciences teaching and learning. In particular, the teachers indicated that technology integration facilitates the development of skills such as communication, critical thinking, collaboration, problem solving and computational thinking. In addition, technology integration was largely perceived to create exciting teaching and learning environment which fosters the enhancement of academic achievement and motivation of learners. Theoretical implications for technology-enhanced teaching and learning are discussed.

Keywords: technology integration, skills, competencies, pedagogical strategies

1. Introduction

The advent of the Fourth Industrial Revolution presents enormous opportunities for pedagogic innovation in various educational settings. As key agents of educational change, teachers are required to embrace digital transformation for progressive and sustainable realisation of stipulated educational outcomes. Considerable emphasis is put on the prompt acceptance and integration of new technologies in teaching and learning (Ilomäki & Lakkala, 2018). New technologies include, but are not limited to, laptops, whiteboards, smartboards, mobile devices, and online learning platforms (Staddon, 2020). According to Demir and Akpinar (2018), mobile devices such as smartphones and tablets continue to transform our lives as they allow connectivity, communication and collaboration in an ever-changing world. Rathore and Sonawat (2015) define technology integration as access to a variety of digital tools that allow learners to apply technological skills to engage with content for a deeper understanding and to solve problems.

The use of digital technologies drives innovation and fosters creativity. Teachers and learners gain new knowledge, skills and experiences through the use of digital technologies in the classroom (Demir & Akpinar, 2018). South African schools have varying levels of capacity to enact, implement and support technology integration. Transformation of learning through technology integration has gained traction as compared to the impact of technological advancement on the transformation of society and social lives of individuals outside the classroom (Ilomäki & Lakkala (2018). As a key 21st century skill, computational thinking guides learners in responding to the challenges they face in their daily lives (Haseski et al., 2018; Weintrop et al., 2016). Computational thinking emphasizes the ideas, strategies and mental behaviours that learners can use to solve unique problems. Through technology integration, learners learn abstraction (use of technology in communication and visualizing data), analysis (use of technology to categorise data), automation (use of technology to learn human anatomy) and modelling (learning human anatomy through 3-D applications) (Weintrop et al., 2016).

Yáñez et al. (2015) argue that innovative teachers create and expand learning opportunities beyond the classroom and this professional attribute is evident in their pedagogies. In contrast to teachers who lack technological pedagogical content knowledge, innovative teachers use mobile technologies and the internet to develop learners' creative and critical thinking skills which can in turn be used in situations outside the classroom (Demir & Akpinar, 2018). Coherent technology integration in various educational settings is influenced by a myriad of factors such as lack of technological knowledge and inability to integrate technology successfully (Azarfam & Jabbari, 2012). The interplay between technology integration and the development of 21st century skills and competencies requires closer scrutiny. It is against this background that this study examined the role of technology integration in the development of 21st century skills and competencies in Life Sciences teaching and learning in suburban South African schools.

2. Literature Review

2.1 Technology Integration in Teaching and Learning

The constantly evolving educational environment presents opportunities to embrace digital transformation with a view to enhance the quality of instruction through pedagogic innovation. Embracing digital transformation requires teachers as key agents of educational change to carefully examine the pedagogic value of technology integration in teaching and learning. The proper use of technology has resulted in true learning by enhancing and transforming today's classrooms into smart learning environments (Firmin & Genesi, 2013). Smart learning environments create resourceful and student-centred learning opportunities that make learning more contextualised, social, reflective and active (Firmin & Genesi, 2013). Teachers play a central role in the integration of technology in the classroom. According to Chen et al. (2009), there has to be coherence among factors that affect the integration of technology in teaching and learning. These factors include teacher beliefs, knowledge and goals. Beliefs influence how the teacher selects and prioritizes the goals of learning. Beliefs influence the teacher's perception of classroom interactions and how they respond and make decisions about tools to be used in the process of learning.

At another pragmatic level, access to technology determines whether teachers will employ technology in their classrooms or not (Farjon et al., 2019). According to Abdu (2018), teachers are mainly responsible for the adaptation and implementation of information and communication technologies (ICT) in the classrooms and if they cannot access these technologies due to poor infrastructure or lack of finances, they cannot create smart environments. Another challenge for most teachers in this educational quest of technology integration is lack of ICT competence (De Vera et al., 2021). Teachers without technological knowledge find it challenging to address technological problems during teaching and learning. ICT competence is important because it allows teachers to devise and be creative enough in implementing technologies that are specific to their learning environments. Successful implementation of technology integration in the classrooms requires availability of digital tools in schools (Atabek, 2020).

2.2 Smart Learning Environments

Smart learning environments are characterised by availability of ICT tools. Availability of affordable ICT tools in classrooms increases the standard of education through ubiquitous and flexible knowledge and skill attainment (Yáñez et al., 2015). Opportunities for learning are expanded beyond the classroom walls through these tools and learners can develop their critical and creative thinking in formal and informal contexts. In addition, the internet allows merging of formal learning and informal learning, giving rise to blended teaching and learning and new pedagogies such as flipped classroom pedagogies. According to Firmin and Genesi (2013), smart classrooms make learning more contextualised as learners are afforded opportunities to apply their skills in real life situations and play an active role in their learning. This implies that smart classrooms enable learners to learn by reflecting on their experiences and as they engage with one another through socialisation. The importance of technological knowledge has been acknowledged by Akcil et al. (2021). This paper argues that technology integration can play a pivotal role in the development of 21st century skills and competencies in Life Sciences teaching and learning within smart learning environments.

2.3 Digital Technologies and 21st Century Skills and Competencies

Digital technologies vary in scope in terms of their potential to promote development of 21st century skills and competencies in the classroom. According to Cheung et al. (2021), digital technologies offer personalised learning. Personalised learning is enhanced through the use of a variety of applications that improve the quality of instruction in the classroom. Cheung et al. (2021) state that digital technologies allow teaching and learning that is based on teacher and learner traits and which is enhanced and improved by preferences and features found in ICT tools. Digital technologies are smart as they make individual development possible. For instance, artificial intelligence,

image recognition and the internet provide insight into one's learning, performance and behaviour, which leads to better understanding and reflection of one's learning and teaching journey. Digital literacy dictates how technologies can be integrated to create smart learning environments. Computational classrooms make provision for digital convenience required for the development of 21st century skills and competencies. Learners can use tools to access all kinds of information and experience technology-oriented classrooms made possible by technology advancements and their successful implementation (Yilmaz, 2021). Through the use of technological tools, learners can acquire information and life skills such as creativity, critical thinking, technology literacy, flexibility and adaptability (Yilmaz, 2021).

3. Theoretical Framework

The study is underpinned by social constructivism as the underlying theoretical framework. By its very nature, social constructivism is a sociological theory of knowledge according to which human development is socially situated and knowledge is constructed through interaction with others. Kapur (2018) posits that social construction of knowledge takes place in various ways and at different locations. More specifically, social construction of knowledge can be achieved through group discussions, teamwork or any instructional interaction in an educational or training institution, social media forum, religious and market places (Kapur, 2018). Social constructivism is also viewed as collaborative learning as it provides opportunities for interaction, discussion and sharing among students. This pedagogical philosophy allows for a range of interactive methods such as class discussions and small group discussions or students working in pairs on given projects or assignments. The underlying factor to the theory is that learners work in groups sharing ideas, brainstorming trying to discover cause and effect, answers to problems or just creating something new to add to existing knowledge.

4. Purpose of the Study

The study examined the role of technology integration in the development of 21st century skills and competencies in Life Sciences teaching and learning in selected South African suburban schools. The empirical investigation is underpinned by the following concomitant objectives.

- To examine the role of technology integration in the development of 21st century skills and competencies in Life Sciences teaching and learning.
- To examine pedagogical affordances of technology integration in relation to the development of 21st century skills and competencies in Life Sciences teaching and learning.
- To identify challenges afflicting coherent technology integration in Life Sciences teaching and learning.

5. Methodology

5.1 Research Design

The study employed an explanatory sequential mixed method design. An explanatory sequential mixed method design provides opportunities for analysis of both qualitative and quantitative data and provides a deeper understanding of the research problem (Ivankova et al., 2006). Furthermore, no specific data is sufficient by itself to fully capture the human behaviour which in this context was human experiences in interaction with digital technologies in the classroom. These two types of data complemented each other in the study and each had their own strengths which allowed for robust analysis (Ivankova et al., 2006).

5.2 Sampling

The study involved 15 purposively selected Life Sciences teachers from five suburban schools in South Africa. The schools were largely well-resourced. The schools were selected on the basis of their capacity to provide meaningful opportunities for technology integration in Life Sciences teaching and learning. The teachers were selected on the basis of the professional experience in Life Sciences teaching and learning.

5.3 Data Collection and Analysis

Quantitative data was collected through the administration of a survey questionnaire with the participants while qualitative data was collected through semi-structured interviews. Quantitative data was analysed using SPSS version 26. Qualitative data was specifically collected to provide elaboration on trends that emerged from quantitative data. The interview data was transcribed and analyzed using both inductive and deductive thematic analysis (Braun & Clarke, 2012). The researchers followed the six phases of thematic analysis, namely: familiarization with data; generation of codes; theme identification; theme consolidation; defining and analyzing the themes; and report production (Braun & Clarke, 2006).

6. Research Findings

6.1 Findings Emanating from Quantitative Data

The teachers' disposition about their professional inclination to integrate technology in Life Sciences teaching and learning is depicted in Figure 1 below. The participants largely demonstrated a positive disposition about their professional agency to integrate technology in Life Sciences teaching and learning. This professional inclination can be attributed to the availability of technological resources at their schools. This implies that availability of essential resources is central to coherent integration of technology in teaching and learning.

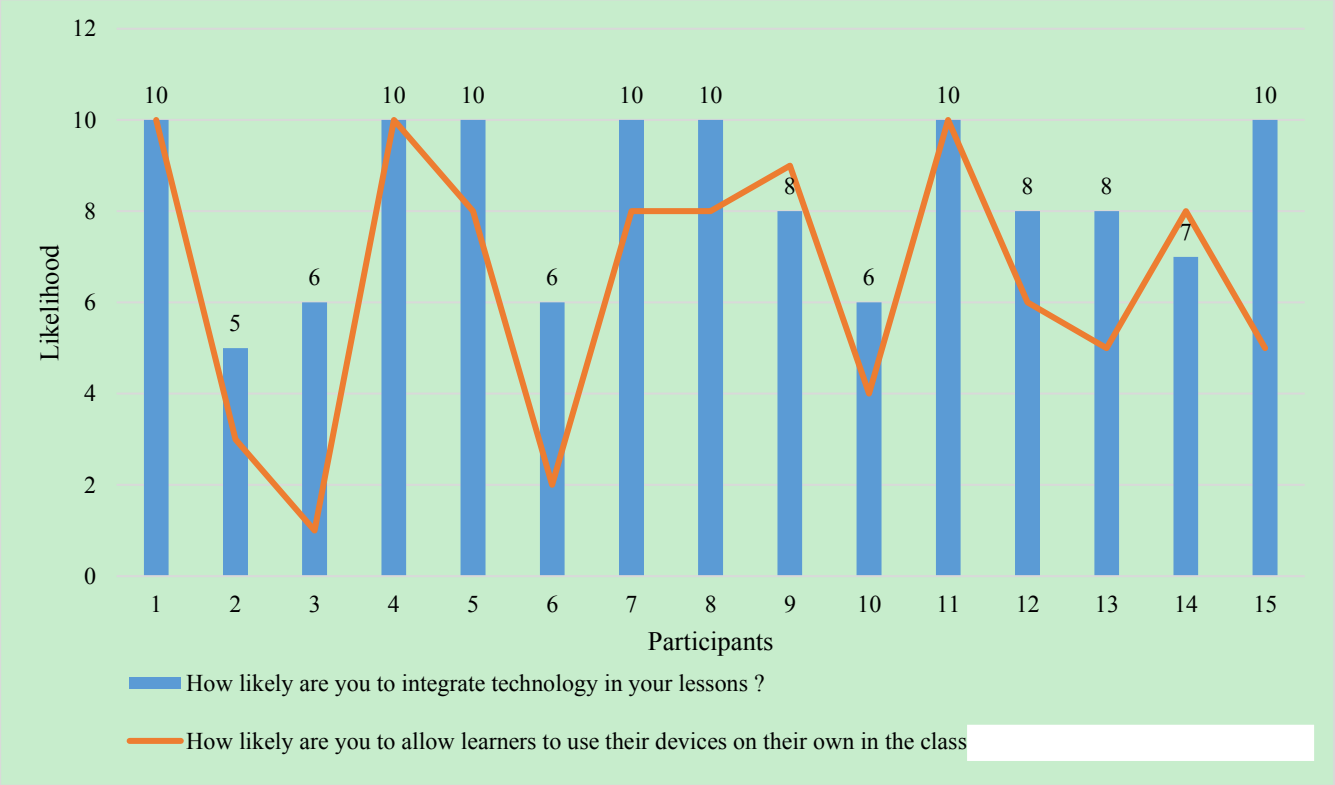

Figure 1. Teachers' inclination to integrate technology in Life Sciences teaching and learning

Table 1 below provides technological devices used by teachers in Life Sciences teaching and learning. Technological devices that were mainly used by the teachers are desktop computers, laptops and smartphones. This pattern of use can be attributed to the type of technological resources available at the selected schools.

Table 1. Technological devices used by teachers in Life Sciences teaching and learning

Device	**Frequenc**
Desktop computer	15
Laptop	14
Tablet	8
Smartphone	12

The teachers used various applications in Life Sciences teaching and learning with a view to foster development of 21st century skills and competencies. Table 2 below provides a list of applications used by the teachers. The applications that were mainly used by the teachers in Life Sciences teaching and learning are WhatsApp, Zoom and Kahoot.

Table 2. Applications used by teachers in Life Sciences teaching and learning

Application	Frequency
WhatsApp	13
Zoom	11
Kahoot	10
Facebook	13
Socrative	8
Class Dojo	4
Near Pod	4

Table 3 below provides perceived 21st century skills and competencies developed in Life Sciences teaching and learning through technology integration. Dominant perceived 21st century skills and competencies that were developed in Life Sciences teaching and learning through technology integration were critical thinking, communication, computational thinking and collaboration.

Table 3. Perceived 21st century skills and competencies that were developed in Life Sciences teaching and learning through technology integration

21st skills and competencies	Frequency
Critical thinking	14
Communication	13
Collaboration	12
Problem solving	8
Computational thinking	11

The teachers adopted various pedagogical strategies when integrating technology in Life Sciences teaching and learning with a view to foster development of 21st century skills and competencies. The pedagogical strategies that were extensively used are small group discussions, collaborative learning, cooperative learning and classroom discussions.

Table 4. Pedagogical strategies adopted by teachers when integrating technology in Life Sciences teaching and learning

Pedagogical strategy	Frequency
Small group discussions	12
Collaborative learning	11
Cooperative learning	13
Inquiry-based learning	9
Classroom discussions	13
Gamification	7

Teachers' perceptions about the pedagogical affordances of technology integration in Life Sciences teaching and learning are depicted in Figure 2 below. The teachers demonstrated a positive disposition about the pedagogical value of technology integration in Life Sciences teaching and learning.

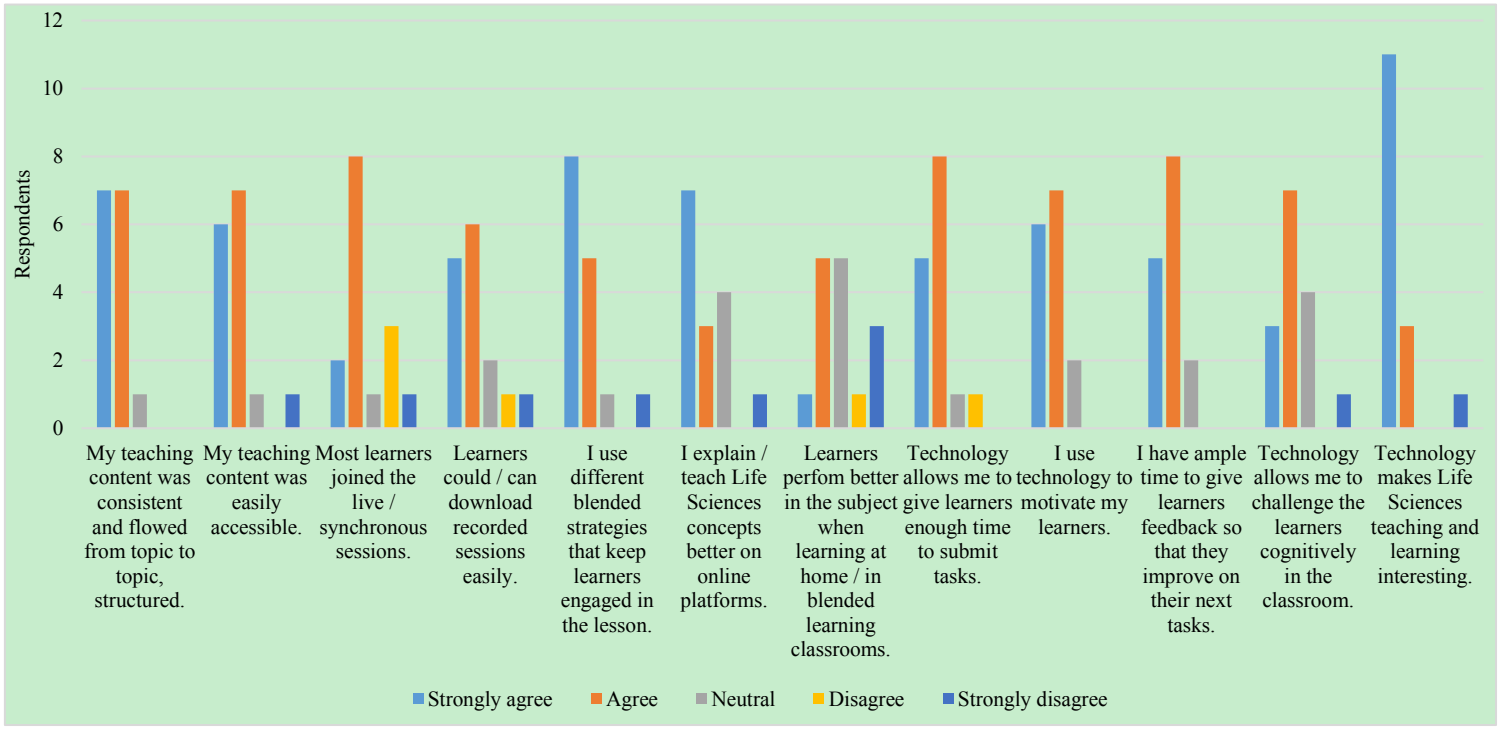

Figure 2. Teachers' perceptions about the pedagogical affordances of technology integration in Life Sciences teaching and learning

6.2 Findings Emanating from Qualitative Data

Findings emanating from qualitative data were clustered according to the key themes that emerged during data analysis, namely: pedagogical affordances of technology integration in Life Sciences teaching and learning, development of 21st century skills and competencies through technology integration, technology integration in Life Sciences teaching and learning and challenges afflicting technology integration in science classrooms.

Theme 1: Pedagogical affordances of technology integration in Life Sciences teaching and learning

The teachers indicated that technology integration in teaching and learning promoted active learner engagement in classroom activities. This can be attributed to the interactive nature of the technological tools deployed. This sentiment is encapsulated in the following excerpt.

The learners are so enthusiastic when using applications such as WhatsApp, Zoom and Kahoot. The use of these applications provides collaborative and interactive learning opportunities.

Furthermore, technology integration was perceived to promote learner autonomy as it provided learners with additional opportunities to revisit the content covered for purposes of consolidating their own conceptual understanding as the following excerpt illustrates.

The use of Kahoot enables learners to learn independently by engaging with quizzes. Learners are excited by provision of immediate feedback which is important for their learning.

Theme 2: Development of 21st century skills and competencies through technology integration

The teachers indicated that technology integration in Life Sciences teaching fosters the development of 21st century skills and competencies. In addition, the teachers expressed fundamental appreciation of the interactive opportunities provided by technology integration in teaching and learning. These sentiments are reflected in the following excerpt.

The use of applications such WhatsApp, Zoom and Kahoot enabled learners to communicate, collaborate, solve problems and indulge in critical thinking. The interactive opportunities provided by the use of these application is crucially important.

Theme 3: Technology integration in Life Sciences teaching and learning

The teachers maintained that careful selection and appropriate deployment of technological resources is of crucial significance. The teachers pointed out that coherent use of technological resources ought to be characterized by deployment of carefully planned instructional tasks and activities. This implies that meaningful use of technological resources in science classrooms requires enhanced technological pedagogical content knowledge. These sentiments are encapsulated in the following excerpt.

Careful planning of instructional tasks and activities is important for lessons to be more meaningful. For instance, the use of Kahoot requires preparation of quizzes in advance.

Theme 4: Challenges afflicting technology integration in science classrooms

Access to bandwidth remains a key challenge afflicting coherent integration of technology in science teaching and learning. Internet connectivity is a key requirement for effective use of technological resources in online learning environments. However, the teachers indicated that the use of technological devices is sometimes plagued by intermittent inadequate internet connectivity. These sentiments are reflected in the following excerpt.

Internet connectivity is a problem sometimes. But it is not an impediment to technology integration in Life Sciences teaching and learning.

7. Discussion

The advent of the Fourth Industrial Revolution presents enormous opportunities for technology integration in science teaching and learning with a view to foster the development of 21st century skills and competencies. The key findings in this study demonstrated that technology integration in teaching and learning promotes active learner engagement in classroom activities. Furthermore, technology integration was perceived to promote learner autonomy as it provided learners with additional opportunities to revisit the content covered for purposes of consolidating their own conceptual understanding. These findings are consistent with a study conducted by Umugiraneza et al. (2018) which showed that technology integration and digital classrooms facilitate teaching and learning and contribute to overall learners' achievement. Technology is a tool that can transform learning and prepare learners to compete in the global arena through provision of access to appropriate applications and tools (Umugiraneza et al., 2018). However, Higgins et al. (2012) argue that technology can disrupt and constrain learning.

The teachers indicated that technology integration plays a pivotal role in the development of 21st century skills and competencies in Life Sciences teaching and learning. According to Camilleri and Camilleri (2017), students can enhance their skills and competencies through integrated digital technologies. The teachers maintained that careful selection and appropriate deployment of technological resources is of crucial significance. The teachers pointed out that coherent use of technological resources ought to be characterized by deployment of carefully planned instructional tasks and activities. This implies that meaningful use of technological resources in science classrooms requires enhanced technological pedagogical content knowledge.

The teachers adopted various pedagogical strategies when integrating technology in Life Sciences teaching and learning. The pedagogical strategies that were extensively used are small group discussions, collaborative learning, cooperative learning and classroom discussions. Utilisation of integrated technologies leads to the discovery of other pedagogical approaches (Higgins et al., 2012). The teachers used various technological devices such as desktop computers, laptops and smartphones when integrating technology in Life Sciences teaching and learning. According to Washington (2017), digital classroom environments are growing in popularity and are proving to be convenient for teachers and students. Digital classroom environments open channels for communicative and collaborative interactions, allow convenient note taking, provide exposure to technology and develop the ability to work on practical problems with ease (Washington, 2017).

7.1 Interpretation of Key Findings in Terms of the Adopted Theoretical Framework

The study is underpinned by social constructivism as the underlying theoretical framework. By its very nature, social constructivism is a sociological theory of knowledge according to which human development is socially situated and knowledge is constructed through interaction with others. Kapur (2018) posits that social construction of knowledge takes place in various ways and at different locations. The teachers adopted various pedagogical strategies when integrating technology with a view to foster the development of 21st century skills and competencies in Life Sciences teaching and learning. In support of this assertion, Kapur (2018) points out that social construction of knowledge can be achieved through group discussion, teamwork or any instructional interaction in an educational or training institution, social media forum, religious and market places. The teachers indicated that technology integration

promoted collaborative learning as learners were afforded opportunities for interaction, discussion and information sharing. Collaborative learning facilitated social construction of knowledge which culminated in the development of 21st century skills and competencies within the context of this study.

8. Recommendations Arising from the Study

There is a critical need to harness pedagogical affordances of technology integration to inculcate 21st century skills and competencies in science teaching and learning. This key strategic imperative can be realised through adoption of innovative pedagogical strategies which are responsive to the critical needs of diverse learners. As key agents of educational change, teachers ought to be implored to fully embrace digital transformation in order to realise stipulated educational outcomes. Embracing digital transformation requires coherent and sustainable enhancement of teachers' technological pedagogical content knowledge.

9. Conclusion

This study demonstrated that technology integration plays a pivotal role in the development of 21st century skills and competences in Life Sciences teaching and learning. The advent of the Fourth Industrial Revolution presents enormous opportunities for pedagogical innovation. Such opportunities ought to be harnessed to foster meaningful teaching and learning to bring about transformative change in society through inculcation of requisite skills. Fundamental socio-economic transformation is predicated on coherent development of requisite skills and this mission can be accomplished through technology integration in science teaching and learning.

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