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Examining the grade 12 life science educators' integration of technology for teaching grade 12 life science curriculum: A case study

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Abstract: This study examines the integration of Information and Communication Technology (ICT) into the Grade 12 Life Sciences curriculum in selected schools within the Karoo District of South Africa. It emphasizes the importance of technological skills among educators and evaluates the effectiveness of digital tools in increasing learner engagement, improving instructional delivery, and supporting contemporary educational objectives. A quantitative research approach was employed, utilizing structured questionnaires to gather data from three Life Sciences educators. The focus was on aspects such as educators' technological knowledge, student participation, and online teaching strategies. The findings reveal significant disparities in ICT knowledge and implementation among educators, which have important implications for learner engagement and digital inclusion. To address inequities related to digital access and educator preparedness, education leaders should prioritize specialized training, infrastructural improvements, and effective regulatory frameworks. Enhancing educators' ICT capacity can lead to increased learner engagement and greater educational equity, particularly in underprivileged communities. The study concludes that successful ICT integration in Life Sciences teaching requires more than just digital tools; it depends on ongoing professional development, robust institutional frameworks, and instructional methods that accommodate learners' diverse technological backgrounds.

Keywords: *Educator knowledge, ICT tools, Technological knowledge, Technology integration.*

1. Introduction

The educational landscape is poised to undergo a significant transformation as a result of the integration of technologies into teaching, and hence the significance of technological proficiencies from educators [1]. Technology integration is more than just adopting gadgets, but a complicated process that calls for educators to acquire professional competencies of technological skills [2, 3]. A more sustainable and inclusive schooling environment can be fostered by educators who possess expertise in technologies [4]. The successful integration of technologies calls for educators' expertise to fit with different school curricula, hence guaranteeing relevant and efficient integration in teaching and learning [2, 3, 5, 6].

Particularly in school subjects, technology integration has the potential to build more responsive, adaptable, and inclusive digital skills [5]. As for the Life Sciences curriculum, the goal of an integrated technology curriculum prioritizes soft skills acquisitions in addition to advanced knowledge and resilience in uncertain circumstances of technological demands [7]. Technology integration is acknowledged as indispensable in the Life Sciences curriculum, which indicates its ubiquitous presence in contemporary education [8]. A comprehensive technology-integrated curriculum in Life Sciences equips learners to navigate the uncertainties of technological demands by prioritizing advanced knowledge alongside the cultivation of soft skills [9]. Technological integration promotes positive attitudes towards technology and develops digital operations and ethical skills from Life Sciences educators who form assets in the skills-driven field of Life Sciences [7, 9].

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For a Life Science educator to become an asset in the skills-driven field of Life Sciences, knowledge of technologies is imperative for the daily implementation activities of teaching the curriculum. For instance, the integration of technologies with project-based teaching, alongside the use of science encyclopaedias, is a sign of the educators' knowledge of technologies [8]. Such educators demonstrate their knowledge of technologies through application and typically employ such technologies to promote learner acquisition of how to use and understand them [10]. There is a distinct characterization of educator knowledge for technologies as those educators who have acquired digital literacy, serving as role models in the use of various technologies during teaching, including in the Life Sciences curriculum [9]. A crucial measure of educator knowledge for technologies in the Life Sciences curriculum is the learners' participation during instruction.

Learner participation is assumed to be a yardstick to measure technology integration during lessons presented by Life Sciences educators. Learner participation in Life Sciences classrooms is significantly improved by the utilization of technology tools, owing to their capacity to enhance a critical aspect of learners' engagement [11]. To support learner participation, it entails the use of digital technologies, including computers, mobile devices, software applications, and online platforms [6]. Additionally, the technological literacy and digital teaching competence of educators can also contribute to learner participation, fostering improved attitudes toward technology, operational capability, and ethics critical competencies in the data-rich field of Life Sciences [7].

To encourage learner participation, technology-enhanced teaching strategies are essential for educators assigned to teach the curriculum [12]. Technology-enhanced teaching strategies significantly boost motivation and learning outcomes, fostering critical thinking, information retention, and learner participation [11]. Educators for the Life Sciences curriculum who utilize digital tool strategies more frequently to disseminate curriculum information often achieve greater learner participation [10]. Educators who engage with Artificial Intelligence tools for learner engagement may assist learners in becoming more adaptive and effective in technology-based lessons, whereby the teachers' technological leadership may stimulate increased learner participation [4].

The study seeks to examine how Grade 12 Life Sciences educators integrate technologies during teaching. The overarching research question is, "How do Grade 12 Life Sciences educators integrate technologies during teaching?"

2. Theoretical Framework

In this paper, a constructivist learning theory is preferred to develop an understanding of how Grade 12 Life Sciences educators facilitate the curriculum with technologies to achieve results where learners become active. The constructivist learning theory emphasizes active learner engagement, inquiry-based learning, and knowledge construction [13, 14]. Constructivist learning environments that are enhanced by technology offer multimedia-rich and interactive experiences that foster a profound understanding through exploration and hands-on activities [15]. Based on the framework, an assumption is created that learners in the Life Sciences discipline would engage in the learning process by establishing connections between new information and prior knowledge through the implementation of constructivist principles using technology. The framework also makes professional demands on educators to become dynamic and to establish learner-centered learning environments that improve conceptual understanding, engagement, and critical thinking with the integration of technologies.

3. Research Methodology

Web questionnaires within a quantitative design approach were employed for data collection in this paper. The web questionnaires were used as data collection instruments designed to gather specific information from respondents [16]. They incorporated a range of statements regarding learner participation, educator knowledge of technologies, and the strategies employed to deliver the Life Sciences curriculum. The scale's simplicity, typically ranging from "Strongly Disagree" to "Strongly Agree", "Disagree to Agree", and "Neutral", made it easy for respondents to understand and respond to the survey items [17]. The original questionnaire questions from a research project were divided into six thematic groups: Section A – biographic information (gender, age, and qualifications); Learner participation (5 items); Educator knowledge of technologies (4 items); and Strategies employed to deliver the Life Sciences curriculum (4 items). This thematic separation was deemed justifiable, as it provided coherent themes and afforded opportunities to comprehensively analyse each topic independently. Trustworthiness in the original instrument was ascertained by consulting senior colleagues and subject specialists.

The data collection process was executed through Microsoft Forms, where a five-point Likert Scale was used, ranging from "Strongly Disagree" to "Strongly Agree", which allowed ease of understanding and response for participants [17]. The validity and reliability of the measurement instruments were enhanced through design review and pretesting by senior experts in the subject field, ensuring they accurately assessed intended constructs and produced consistent results [18, 19]. For data analysis, responses from the Google Form were compiled and converted into tables as soon as submissions were received. The results were analysed and visually represented using bar graphs derived from the percentage breakdown of each construct. The survey was administered to 11 participants selected from various schools within the case study. Their inclusion was based on their roles as educators capable of providing informed insights on the topic, and their participation was voluntary and informed.

4. Literature Review

This section of the paper presents literature to further ground the objective, organized under the constructs of educator knowledge, educator knowledge of technologies, and learner participation. Educator knowledge was emphasized in a study by Adipat, et al. [20] which highlighted the importance of understanding both the advantages and disadvantages of different educational materials as a key component of technological literacy. In another study, it was established that educator knowledge became especially crucial during the COVID-19 pandemic, when most educators needed to be sufficiently knowledgeable to integrate technology into classroom instruction Pratami and Ajisuksmo [21]. Adipat, et al. [20] also found that educator knowledge of technologies empowered teachers to search for educational technologies suitable for integration into their lessons, thereby enhancing both the effectiveness of teaching and the development of their technological competence.

4.1. Educator's Knowledge of Technologies

Several studies have investigated educators' knowledge of technologies during teaching. In the report by Chomunorwa and Mugobo [22] difficulties in integrating technology into classrooms were highlighted, where the adoption of technologies was perceived as ineffective, indicating low levels of technological knowledge among educators. Similarly, Wahyudi, et al. [23] found that many educators failed to keep pace with the rapid advancement of technology, which hindered their ability to integrate it effectively into the learning process. A study by Shi, et al. [24] corroborated these findings, noting that educators often struggled to identify innovative tools and experienced difficulties adapting to new technologies, particularly those working in under-resourced environments. Educators who work with vulnerable learners or who possess lower levels of AI literacy may face additional challenges in incorporating technology into their teaching practices [25]. This can result in a digital divide, where some learners benefit from technology-enhanced learning while others are left behind.

In summary, while educator proficiency in technology is essential in modern education, it presents notable challenges, including the need to keep up with rapid technological changes, address subject-specific demands, and ensure equitable access to technology. Continuous professional development, adaptive competence frameworks, and targeted support for educators serving diverse learner groups are necessary to overcome these barriers [25].

4.2. Learner Participation

Learner participation is an important barometer for assessing educator knowledge of technology integration. Several studies have explored learner participation in the context of technology-enhanced teaching. According to the study by Junger, et al. [26] learner participation increased significantly when various applications from digital devices and online platforms to robotics were employed during lesson delivery, resulting in more positive learning experiences. Learner engagement on technological platforms can also be enhanced through the implementation of real-time behavioral analytics and machine learning, which allow for timely recommendations and interventions to support learner success [27].

Positive teacher-learner relationships are also essential for fostering learner participation, as they support academic skill development, social functioning, and classroom engagement [28]. While recent research acknowledges limitations in fully capturing the directionality of these associations, the importance of such relationships in promoting learner participation remains evident. Digital technologies have transformed traditional teaching into interactive, learner-centered experiences. These technologies are vital in equipping learners with the competencies required to succeed in an interconnected global landscape by encouraging self-directed learning, critical thinking, and collaboration [29]. In conclusion, the use of advanced technologies and the cultivation of positive teacher-learner relationships contribute to improved academic performance, increased engagement, and better preparedness for the demands of the future workforce. However, realizing these benefits fully requires addressing challenges such as the digital divide and data management concerns [27, 29].

Educators must be aware of the challenges that arise in the classroom, even though learner participation is crucial for understanding technology integration. The accelerated integration of digital technologies into education has revealed both opportunities and challenges in promoting educational inclusivity. Ensuring digital equity remains a significant concern, as learners without adequate connectivity, devices, or digital skills face additional barriers to participation and are less able to benefit from digital opportunities [30]. This digital divide risks exacerbating existing disparities in learner participation. Learners also face unique challenges in online learning environments, including academic disruptions, technological limitations, financial strain, and psychological stress. These difficulties are often intensified by time zone differences and social isolation, all of which can significantly hinder engagement and participation [31]. Moreover, the effective integration of technology in classrooms may be limited by educators' lack of confidence or preparedness to develop digital competencies among their learners [32].

4.3. Online Teaching Strategies Used for Technological Teaching

Technological teaching strategies offered online provide a variety of benefits, including adaptability to the needs of modern learners, increased engagement, flexible resource utilization, and enhanced skill development. However, successful implementation requires a supportive culture of innovation, robust technological infrastructure, and adequate faculty training [33, 34]. The incorporation of online teaching strategies has also been shown to improve learners' clinical reasoning and problem-solving abilities [35]. These technologies introduce novel paradigms in teaching and learning that can significantly enrich the overall educational experience. Online teaching enables the integration of diverse multilingual and multimodal resources, further enhancing learners' engagement. To support this, educators may develop their translanguaging proficiency and draw from multiple sources of knowledge to better facilitate learners' learning [36]. This adaptability in resource use can result in more dynamic and effective lessons. Online learning environments also offer learners deeper engagement with course content, peers, and educators. Immersive experiences can be achieved through the application of advanced instructional technologies and interactive features [34]. Moreover, course management, content delivery, and learner interaction are streamlined through the implementation of high-quality learning management systems (LMS).

Online teaching strategies, including adaptive learning technologies, blended learning, and online collaboration platforms, can effectively engage learners and optimize learning outcomes for millennial learners [33]. These methods are tailored to accommodate the unique learning preferences and characteristics of the millennial generation, preparing them for an evolving digital landscape. Papaioannou, et al. [37] found that online and virtual learning environments support a wide range of pedagogical approaches, including experiential learning, project-based learning, and collaborative teaching. By promoting engagement, fostering enriched collaboration, and stimulating creativity, these innovative environments have the potential to significantly enhance the quality of higher education.

Effective online learning is significantly impeded by technical issues and the digital divide. Inadequate technical support, weak internet connectivity, and limited access to essential devices pose major challenges for learners [38, 39]. These obstacles can disrupt the learning process and exacerbate disparities among learners. Moreover, cognitive processes may be negatively influenced by the affective components of online learning, such as stress, frustration, or isolation, further hindering learner engagement and performance.

The absence of face-to-face interactions in online environments can lead to feelings of isolation and reduced engagement, even though both positive and negative emotions influence learning [40]. This emotional disconnect may impair learners' motivation and diminish the overall learning experience. The pandemic-driven transition to online platforms further underscored concerns related to accessibility, instructional methodologies, and the integration of appropriate technologies [41]. In summary, despite the various drawbacks associated with online teaching strategies for technological education, ongoing efforts to overcome these challenges through the adoption of emerging technologies, innovative instructional design, and enhanced infrastructure can help maximize the potential of online learning and ensure inclusive, high-quality education [24, 38].

5. Results and Analysis

This section of the results is based on the constructs mentioned in the paper earlier about learner participation, educator knowledge about technology, and online teaching strategies used in the Life Sciences curriculum.

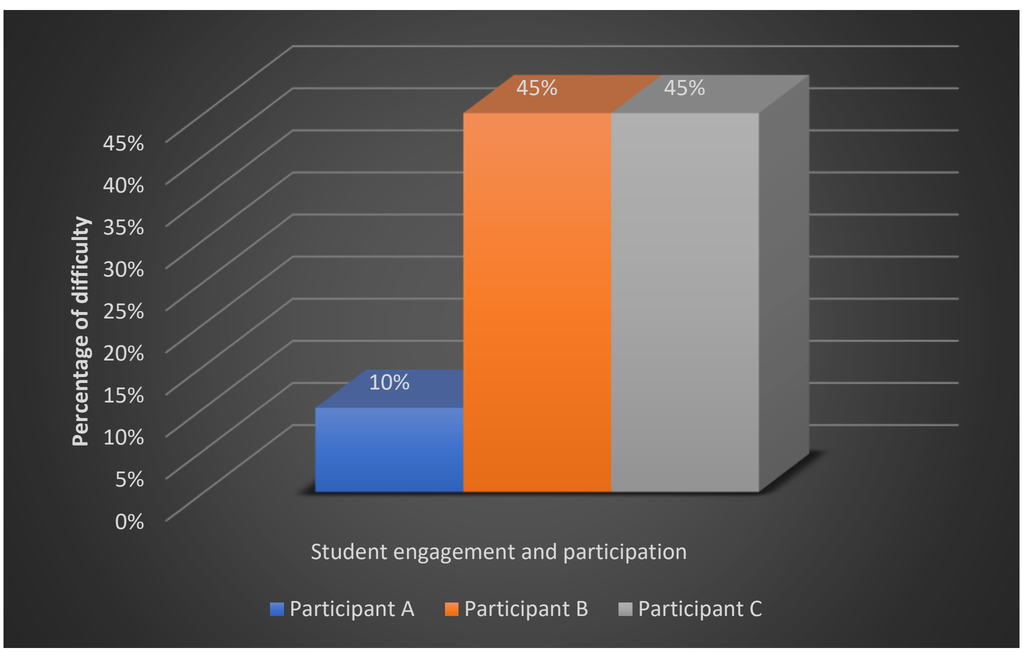

Figure 1.
Learners' participation.

Figure 1 presents results that identify learner participation as a challenge that Grade 12 Life Sciences educators experienced when integrating ICT into teaching. It is observed from Figure 1 that all the participants (A, B, and C) experienced learner participation challenges when integrating ICT into teaching the Grade 12 Life Sciences curriculum. Both Participants C and B were equally affected at 45% by the learner participation challenges. On the other hand, Participant A experienced both challenges at 10%. From the results taken together (for Participants C and B), it may be inferred that the Grade 12 Life Sciences educators experienced learner participation challenges in the delivery of the curriculum.

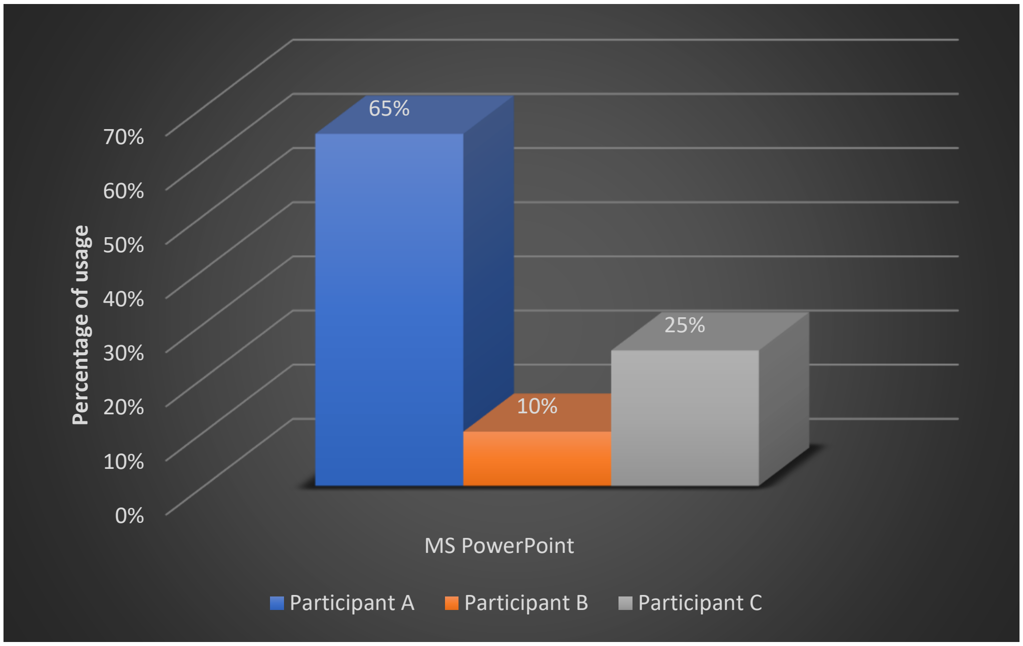

Figure 2.
Educator knowledge of technologies.

Figure 2 illustrates the data regarding the knowledge of technology (ICT tools) among three participants: A, B, and C. The findings indicate notable differences in the extent of ICT knowledge among the participants. Participant A exhibits the highest level of knowledge at 65%, indicating a robust understanding and proficiency with ICT tools for educational applications. This could suggest a greater level of training, experience, or personal initiative in the adoption of technology. Participant C demonstrates a 25% proficiency, reflecting a moderate understanding of ICT knowledge. This indicates that although Participant C possesses some familiarity with technology, there are probable deficiencies that could impede successful ICT integration. Participant B indicates the lowest level of ICT knowledge at 10%, highlighting significant constraints in comprehending or utilising ICT tools within educational environments. This may stem from limited access to development opportunities or inadequate support systems for technology implementation.

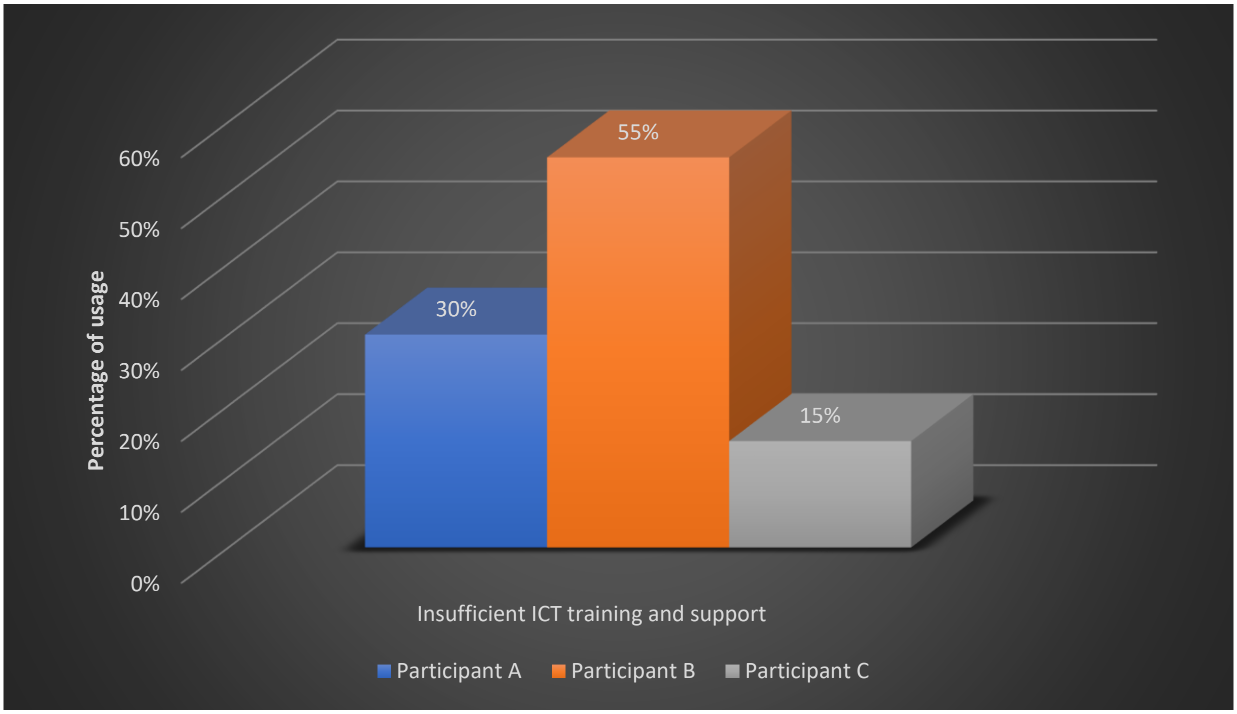

Figure 3.
Online strategies used for Life Sciences.

Figure 3 illustrates the percentage of online strategies utilized by three participants in the Life Sciences curriculum. The data indicates that Participant B had the highest utilization rate (55%), followed by Participant A (30%), and Participant C had the lowest usage at 15%. The results indicate that Participant B is more likely to employ online strategies for Life Sciences instruction, which may be indicative of a higher level of confidence or access to ICT resources. Conversely, Participant C's low percentage may be attributed to a preference for traditional teaching methods, infrastructure challenges, or a lack of digital literacy. Participant A exhibits moderate utilization of online strategies, placing her in the middle of the spectrum. In general, the discrepancies in Figure 3 indicate that educators have varying levels of ICT adoption, which underscores the necessity of providing targeted training and resources to guarantee the equitable integration of digital technologies into Life Sciences education.

6. Discussion

Three figures in this paper facilitated the development of the composition by providing some form of support for the objective. The objective was justified by the action, which suggested that each table could be independently connected to a specific construct that could be measured with a specific rationale.

The results of Figure 1 are consistent with research that emphasizes learner participation as a crucial teaching challenge. A study by Fadilah, et al. [42] found that learner participation significantly impacts academic performance and that low participation and engagement often lead to reduced motivation and emotional attachment to learning. Similarly, Karthikeyan, Abirami, and Thangavel [23] identified specific challenges such as sustaining interest, organizing effective teaching-learning activities, and enhancing both formative and summative assessments. Furthermore, studies emphasize the difficulties of maintaining learner engagement throughout ICT integration. Successful implementation of educational technologies may be hindered by factors such as equity concerns, resistance to change, and technological constraints, as noted by Ranbir [43]. Karunakaran and

Dhanawardana [5] also pointed to issues such as limited resource access, infrastructure disparities, gaps in digital skill development, and restrictive school policies that hinder learners from utilizing technology. These challenges are particularly relevant in Life Sciences classrooms, where curriculum delivery increasingly depends on ICT integration. Collectively, the research indicates that addressing learner engagement and participation is critical to ensuring the effective use of ICT in Grade 12 Life Sciences teaching and learning.

The results of Figure 2 align with current research emphasizing the importance of educators' technological literacy. As noted by Adipat, et al. [20] understanding the strengths and weaknesses of various educational materials is a fundamental aspect of technological literacy, which enables educators to effectively integrate technology into lesson plans, thereby enhancing learner engagement and academic outcomes. The observed differences among participants suggest varying levels of technological literacy, which may influence their ability to engage learners and deliver effective teaching. Furthermore, research highlights an intensified emphasis on technology integration in education following the COVID-19 pandemic. Pratami and Ajisuksmo [21] reported that the pandemic accelerated the use of digital tools such as Google Classroom, underscoring the urgent need for sufficient ICT knowledge among educators. While many educators have developed adequate technological competencies Pratami and Ajisuksmo [21] the disparities reflected in Figure 2 suggest that not all have benefited equally from this transition, possibly due to unequal access to professional development opportunities or inconsistent institutional support.

Recent studies highlight the essential role of educators' ICT competence in improving teaching quality and learner outcomes. Azubuike, et al. [44] found that educators' ICT knowledge positively influences their teaching effectiveness and learners' academic performance in schools. This corresponds with the noted high proficiency of Participant A, suggesting a possible relationship between ICT competence and instructional effectiveness. Moreover, the integration of technology in education has demonstrated the potential to enhance learner engagement and academic achievement. Effective use of technology has been shown to improve learner involvement in the learning process, leading to stronger academic results and better problem-solving skills. However, the success of such integration depends on several factors, including educators' technological proficiency, learners' access to devices and internet connectivity, and institutional support from the school. The COVID-19 pandemic further underscored the importance of digital literacy for educators. Pratami and Ajisuksmo [21] reported that the pandemic accelerated the adoption of tools such as Google Classroom, emphasizing the need for adequate ICT skills among educators to effectively utilize these platforms. Additionally, educators' perceived ICT competence has been linked to their well-being and emotional exhaustion. Li and Wang [45] found that when educators feel unprepared in ICT use or lack sufficient technical support, the integration of technology can lead to increased stress and emotional exhaustion, negatively affecting their overall well-being.

The data reveals significant disparities in ICT knowledge among educators, potentially affecting their capacity to integrate technology effectively into the classroom. The notable disparity between Participant A and the other two participants indicates the necessity for focused interventions, including development programs or collaborative knowledge-sharing opportunities, to address the gap in ICT competencies among educators.

The results of Figure 3 align with the broader body of literature on the advantages and challenges of integrating online teaching strategies. Online technological teaching strategies have been shown to enhance skill development, support flexible resource use, and boost learner engagement [33, 34]. The findings suggest that Participant B may have greater access to these benefits, while Participant C's lower utilization percentage may reflect challenges such as insufficient training, infrastructure constraints, or resistance to adopting new technologies. In addition, the incorporation of online strategies is associated with enhanced cognitive abilities, including clinical reasoning and problem-solving [35]. This suggests that educators who effectively implement online strategies in Life Sciences classrooms may provide learners with a more intellectually stimulating and interactive environment.

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The educational experience is further enriched by the capacity of online platforms to support multilingual and multimodal resources, enabling educators to accommodate diverse learning styles [36]. Participant A's moderate adoption rate of online strategies (30%) may indicate a partial implementation of these methods, which could be improved through targeted interventions.

Solano-Gutiérrez [38] and Tshering [39] emphasize that the digital divide and technical issues remain substantial barriers to the effective adoption of online education. Inadequate technical support, poor internet connectivity, and limited access to digital devices can create disparities between educators and learners, potentially explaining the differing adoption rates observed in Figure 3. Furthermore, the lack of face-to-face interaction in online environments may contribute to emotional disconnection, which can negatively impact learner engagement and motivation [40]. The COVID-19 pandemic accelerated the shift to online platforms, raising concerns about instructional approaches and equitable access [41]. The findings in Figure 3 highlight the ongoing need for support in integrating online strategies effectively into Life Sciences education. To address these challenges and ensure inclusive, high-quality learning, scholars such as Shi, et al. [24] and Solano-Gutiérrez [38] advocate for the use of improved infrastructure, innovative instructional design, and emerging technologies. In summary, the variations in the use of online strategies depicted in Figure 3 reflect broader trends in ICT integration within education. While online strategies offer numerous advantages, their success depends on factors such as technological infrastructure, educator preparedness, and institutional support. Ultimately, the integration of online teaching strategies in Life Sciences classrooms can be enhanced through targeted interventions, leading to improved educational outcomes for learners.

7. Recommendations

The allocation of funds by authorities should be directed toward the enhancement of ICT infrastructure and the provision of professional development programs for educators. To guarantee the consistency and efficiency of technology utilization, educational institutions should establish explicit policies and guidelines for the integration of ICT. Learner engagement and resource accessibility can be enhanced by promoting parental support and community involvement in ICT-driven learning. To implement the requisite modifications, educational institutions should evaluate the efficacy of ICT integration through learner feedback, performance analysis, and educator reflections. Inclusivity can be achieved by addressing disparities in technology access through alternative offline learning methods, subsidized internet access, and device distribution programs. By implementing these recommendations, schools can improve learner engagement, enhance overall teaching and learning experiences, and optimize ICT integration in Life Sciences education.

8. Conclusion

Although ICT integration poses obstacles, the potential advantages are significantly greater than the constraints when suitable strategies and resources are made available. The integration of technology into the Life Sciences curriculum can significantly improve the teaching and learning outcomes by ensuring that learners are equipped with the requisite digital skills to succeed in an evolving educational landscape, with a concerted effort from educators, policymakers, and stakeholders. Future research should investigate the long-term effects of ICT integration on learner engagement and performance while simultaneously confronting the challenges of digital accessibility and equity in education.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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