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Information and Communications Technology Integration in Bahamian Public High School Biology Classrooms

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Walden University
2022

Abstract

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by

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MA, Griggs University/Andrews University

BSc, University of the West Indies

Project Study Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Education

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Abstract

More research on information and communications technology (ICT) use for teaching and learning is needed, particularly since the almost global transition from traditional face-to-face to virtual classrooms forced by the COVID-19 pandemic. The problem addressed in this current qualitative project study was the reported challenges experienced by teachers integrating ICT into the delivery of the biology curriculum in Bahamian public high school classrooms. The purpose of the study was to explore the biology teachers' ICT integration into their virtual classrooms during the COVID-19 pandemic. The study was grounded in the technological pedagogical and content knowledge conceptual framework. Three research questions focused on the teachers' decisions to use ICT in their biology classrooms, their challenges with ICT integration and their mitigation of challenges, and their needs for improving ICT use. A purposeful sampling procedure yielded eight participants, and data were collected using semistructured virtual interviews on Zoom. Coding analysis of interview data revealed several emergent themes and four key findings: (a) ICT selection hinged on logistics and teachers' technological and pedagogical knowledge; (b) teachers experienced infrastructural, technical, and pedagogical challenges but found solutions; (c) the ICT integration was valuable; and, (d) teachers wanted to improve their ICT use to enhance their teaching and students' learning in remote classrooms. A position paper was developed to be a positive social change catalyst by informing local education policymakers and stakeholders about biology teachers' suggestions for needed modifications to better support teachers in remote instructional delivery.

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Dedication

I dedicate the doctoral degree I have finally earned to my immediate Johnson family and my extended Nembhard family for their conviction that I could accomplish the task even when I had doubts. I am grateful for their encouragement and unwavering support. I also dedicate the degree to my very good friends. Thank you for your words of encouragement.

Acknowledgments

I acknowledge my chair's tremendous contribution to the completion of my doctoral journey. Despite only a few months as chair, Dr. Darci J. Harland's dedication to the task was unwavering. Her constructive critique was crucial in developing a robust study. She dismissed my fears and uncertainties as groundless and refused to allow me to quit. Her interest in my research made me almost believe it was hers, and I was her only mentee! Dr. Harland is the best chair a student could have. I am grateful to my committee member and methodologist, Dr. Paula Dawidowicz, for ensuring the preciseness of my study's methodology and the validity of any data points presented. Under her skillful guidance, my data collection and data analysis processes led sequentially and unerringly to the results and findings. I am saddened to not have her complete my doctoral journey with me. Thank you, Dr. Heather Pederson, for filling the space created by her absence. I acknowledge the contributions of University Research Reviewer Dr. Bonita Wilcox in strengthening my project study, and the Form and Style editor Dr. Joseph Gredler for improving my manuscript's quality.

I am grateful to the biology teachers in the Bahamian schools who shared their experiences integrating ICT into virtual classrooms. Without their input, I would have had no study. I commend the teachers for doing a great job ensuring that Bahamian students' learning is undisrupted amid the disruptions of the COVID-19 pandemic.

I thank God for His guidance and for working out each obstacle in an always timely manner. All I needed to do was to stand still and see His salvation.

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Section 1: The Problem

Research has revealed poor achievement in biology for students at all academic levels (Reece & Butler, 2017; Shaheen & Khatoon, 2017). However, research has also revealed improved results from ICT integration into biology curricula as well as other curricula (Kapici et al., 2020; Naji, 2017; Nasr, 2020; Sargent, 2017; Shaheen & Khatoon, 2017). The onset of the COVID-19 pandemic in 2019 precipitated drastic changes in education, the main one being the almost universal replacement of face-to-face (FTF) instruction with remote learning facilitated with ICT tools. Strategies for providing students an education in the midst of the COVID-19 pandemic are still being explored (Kara, 2021; The World Bank, 2020a). A clear pathway is yet to be charted (N. Johnson et al., 2020), and outcomes of the remote education initiatives on students' learning appear uncertain (Kara, 2021). In the current study, I explored teachers' ICT integration into the biology curriculum in Bahamian public high schools. In Section 1, I introduce the local problem, include the study's rationale, provide some definitions of terms, explain the significance of the study, and provide the research questions that organized the study.

The Local Problem

The local problem at a Bahamian public high school was that biology teachers experienced challenges integrating ICT into their classrooms to facilitate the delivery of the biology curriculum, according to internal institutional documents from 2017–2019 and biology teacher reports. One challenge to proper ICT integration reported by a biology teacher at the Bahamian public high school was an insufficiency of ICT resources in the biology classrooms (personal communication, October 6, 2017). According to internal school documents, including a November 28, 2017, survey of ICT tools in the school's biology laboratories, only two of the three rooms contained interactive whiteboards, and no laboratory was internet accessible. A biology teacher at the school noted the inherent challenge for the then nine biology teachers to fully use this ICT resource for instruction or assessment (personal communication, November 28, 2017). Additionally, the teacher indicated that a class set of 25 tablet computers supplied to the science department in September of 2018 had not yet been used in biology classrooms. The teacher suggested that failure to use the tablet computers related to scheduling issues for use among the school's more than 900 biology students and the lack of educational programs on the devices (personal communication, April 29, 2019).

Another biology teacher at the school identified a lack of information technology support for the limited ICT resources and inadequate professional development (PD) training as challenges for integrating ICT into the curriculum (personal communication, January 23, 2018). Additionally, a biology teacher from the school reported challenges with inconsistent or unavailable internet connectivity, which was said to severely limit the use of ICT in the biology classrooms (personal communication, June 6, 2018). Another biology teacher from the school opined that the challenges experienced by teachers in the integration of ICT into their biology classrooms were inadequately addressed (personal communication, June 6, 2018).

Table 1 displays biology results from the Bahamas General Certificate of Secondary Examinations (BGCSE) for the school, which is referred to as School B. The biology results are for the years 2016 through 2019—the years immediately preceding the COVID-19 pandemic.

Table 1

BGCSE Biology Results for Bahamian Public High School B (2016–2019)

Year	% A-C grades
2016	25.7
2017	40.2
2018	46.8
2019	29.8

Note. Data were available in the public domain and were obtained from the Examination and Assessment Division of the then Ministry of Education, Science and Technology (MOEST), now the Ministry of Education and Technical and Vocational Training (MOETVT).

The data reflect poor biology performance, as less than 50% of the students at School B achieved pass scores of A–C in biology on the national examinations for the years 2016–2019. Although correlation between teachers' challenges with ICT integration into their biology classrooms and students' biology performance at School B has not been established, a biology teacher at the school suggested a need for research to understand how ICT integration into the biology curriculum could improve the students' biology performance (personal communication, November 28, 2017).

The challenges to ICT integration cited by the biology teachers in School B are not unique to the school. The problem was also mentioned in the professional literature. Researchers such as Al Ghazali (2020), Powell and Bodur (2019), and Withers et al. (2021) identified similar challenges with ICT integration into curricula. Basargekar and

Singhavi (2017) from their study on teachers' use of ICT in Indian classrooms concluded that teachers play a vital role in effective ICT implementation in schools. However, teachers have not always achieved successful ICT implementation (N. Johnson et al., 2020; Jung et al., 2021).

The purpose of the current qualitative study in a Bahamian setting was to explore teachers' ICT integration into the public high school biology curriculum. The challenges with ICT integration could be preventing the biology teachers from using ICT optimally and might also be related to students' low biology achievement. In exploring the biology teachers' ICT integration into their classrooms, I wanted to know the specific ICTs the teachers were using in their biology classrooms and the tasks for which they were using them. I wanted to know the challenges surrounding the teachers' selection and use of ICT in their biology classrooms, and I wanted to understand how the challenges with ICT integration affected the teachers' ICT use in their classrooms. Finally, I desired to discover the teachers' ICT needs to transform their pedagogy to positively impact their students' biology achievement. The study's findings may help reduce the challenges for biology teachers integrating ICT into their local classrooms, aid teachers in transforming their pedagogy, and redress students' poor biology performance in public high schools in the Commonwealth of the Bahamas. I applied the data I collected about the biology teachers' use of ICT for delivering the biology curriculum to the development of the project deliverable for my study.

Rationale

In this qualitative study in a local Bahamian setting, I explored teachers' ICT integration into the public high school biology curriculum. McKenzie (2019) publicized the Bahamas' Ministry of Education, Science, and Technology (MOEST) technology goal of ensuring that all public schools received new educational technologies and received appropriate upgrades to existing ones for the education of students in 21st century classrooms. This thrust to invest in educational technology by the MOEST of the Commonwealth of the Bahamas as in many other developing countries, reflected the reputed benefits of ICT for improving teaching and learning (see Dintoe, 2018; Ergado, 2019; McKenzie, 2019). However, ICT integration efforts are fraught with challenges. Challenges include inappropriate software and inadequate infrastructural support for the ICT (Alemu, 2017; Al Ghazali, 2020; Fletcher & Nicholas, 2018; Withers et al., 2021), insufficient training in ICT for the teachers (Laronde et al., 2017; Powell & Bodur, 2019), and lack of sound pedagogical practices for the ICT policy (Ergado, 2019; Heitink et al., 2017; Saxena, 2017). The local teachers' reports of similar challenges integrating ICT into their Bahamian public high school biology classrooms suggested a need to conduct further investigation on ICT use in education in the Bahamian setting.

Researchers such as Basargekar and Singhavi (2017); Fletcher and Nicholas (2018); N. Johnson et al. (2020); and Jung et al. (2021) have investigated the challenges of integrating ICT into educational curricula. Research findings highlighted challenges that were similar to those reported by biology teachers in the Bahamian setting. Recommendations for mitigating the challenges to improve the ICT integration's effectiveness included providing teachers with appropriate software and ICT training (Basargekar & Singhavi, 2017) and providing essential PD in ICT for teachers (Laronde et al., 2017; Powell & Bodur, 2019). More recently, A. Koehler and Farmer (2020) and Sumer et al. (2021) reiterated the need for PD to improve teachers' ICT integration into their new remote classrooms. The reports from the biology teachers in the Bahamian public schools regarding their challenges with ICT integration did not indicate that these recommendations have been vigorously adopted in their local schools.

Literature search on the topic of ICT integration in education yielded little information about the outcomes of the integration in Bahamian schools. Students' low biology achievement at School B, even with ICT integration into the biology classrooms, was concerning. Quantitative research to explore the possible relationship between ICT integration and the students' poor biology performance was a consideration for my capstone study. However, for reasons including a desire to *talk* with teachers and *hear* about their ICT integration experiences, I became more interested in a qualitative exploration of local biology teachers' challenges integrating ICT into their Bahamian public high school biology classrooms. As a former biology teacher, my close professional association with other biology teachers was a strong motivator for conducting the study. I had observed biology teachers' efforts to integrate ICT into their classrooms and heard their frustrations with the process.

Furthermore, being enrolled in Walden University's Doctorate in Educational Technology program broadened my appreciation of innovative technology's potential to transform teaching and learning and effect social change. I am now in a stronger position to advocate for technological integration into education and am convinced that providing local biology teachers with effective ICT integration tactics could improve students' biology performance. Valuable recommendations for effective ICT integration into the biology curriculum could emerge from the local teachers' experiences using ICT in their classrooms. Although educational policymakers might be aware of the transformational potential of ICTs in education, they might be unaware of how the realities of local classrooms could preclude the effective utilization of the technologies. Reports from the professional literature about teachers' challenges with ICT integration into educational curricula, the local teachers' statements about their challenges, and the poor biology performance of students at School B were the motivators prompting me to explore biology teachers' ICT integration into their classrooms in the Bahamian setting.

Definitions of Terms

Content knowledge: Teachers' knowledge of the subject matter to be learned or taught (Mishra & Koehler, 2006).

Curricula: The list of courses taken in a school. The curriculum covers the targets expected to be achieved, content associated with targets, educational conditions, and assessment conditions (Akınoğlu, 2017).

Epistemology: The philosophical underpinnings of an individual's beliefs regarding the nature of knowledge and how it is derived or created (Yin, 2016).

Information and communications technology (ICT): A general term referring to different technological materials and resources used for communication, creation, organization, storage, dissemination, utilization, and management of information or knowledge (Meenakshi, 2013, as cited in Ergado, 2019).

Information and communications technology as applied to education: Those technologies including computers, smartphones, iPads, tablets, and internet connections used in the classroom (Lersilp & Lersilp, 2019).

Information and communications technology integration: The engagement of students in collaborative work and real-world problem-solving through effective exploitation of information and communications technologies (Koh et al., n.d.).

Pedagogical knowledge: Teachers' knowledge of the processes and practices of teaching and learning that requires an understanding of cognitive, social, and developmental theories of learning and their applicability to students in the classroom (M. J. Koehler & Mishra, 2009).

Syllabus: A planning tool that communicates class requirements and documents teaching-related tasks such as examination preparation and assessment procedures (Stowell et al., 2018).

Teacher effectiveness: Teachers' ability, skills, knowledge of pedagogy, and knowledge of subject content that is used to bring about student learning (Akram, 2019).

Teachers' PD in ICT: Training sessions for in-service teachers in the use of ICT for learning (Asensio-Pérez et al., 2017).

Technological pedagogical and content knowledge (TPACK): A complex interaction among content, pedagogy, and technology that produces the knowledge needed to integrate technology into teaching effectively (M. J. Koehler & Mishra, 2009).

Technology integration: A process of combining different pieces of technology to support student learning (Siegel & Claydon, 2016).

Technology knowledge: An evolving understanding and mastery of technology for information processing, communication, and problem-solving that develops from a generative, open-ended interaction with technology (M. J. Koehler & Mishra, 2009).

Significance of the Study

Findings from this current qualitative study may be significant. First, this study may add to the body of knowledge needed to solve the problem of local teachers struggling to achieve proper integration of ICT into their biology classrooms to improve student learning outcomes. Second, this current study was unique because it addressed a gap in practice between experts' recommendations for mitigating teachers' challenges with ICT integration and local teachers' struggles with integrating ICT into the Bahamian public high school biology curriculum. The study has significance at the local level because it may provide stakeholders with a better understanding of ICT integration challenges into Bahamian public high school biology classrooms. Participants' responses to interview questions may provide suggestions for improved ICT integration into the Bahamian public high school biology curriculum. Third, the study's outcomes may influence policy decisions on ICT integration into Bahamian schools at other academic levels and for other curricula. Fourth, the research could be a catalyst for positive social change as education policymakers, school boards, and other education stakeholders might be better informed about the need for possible modifications to curricula, PD training, and ICT funding that could improve remote teaching and learning. Positive social change might also accrue when educators are provided with knowledge about using the technologies available to them and can incorporate the technologies into the learning process successfully. Last, the study could be of particular importance in helping to provide the best educational offering for students in the Bahamas during the COVID-19 pandemic. The COVID-19 pandemic accentuates the critical need to effectively integrate ICT to produce the best learning environments for today's classrooms and classrooms of the future. The study's findings might be transferable from the local Bahamian setting to the global educational profession.

Research Questions

The research questions (RQs) were related to the current study's problem and purpose. I also aligned the RQs with the study's conceptual framework. The three interrelated RQs provided the foundation for an in-depth exploration of the local teachers' ICT integration into their biology classrooms. The RQs were crafted to help me understand how the teachers used ICT in their classrooms, recognize the challenges they encountered with integrating ICT into the local biology classrooms, and elicit their needs to improve ICT use to positively impact students' biology achievement. The RQs were as follows:

RQ1: How do local public high school teachers decide to use ICT in their classrooms to deliver the biology curriculum?

RQ2: What challenges do local public high school biology teachers experience in their integration of ICT into their biology classrooms?

RQ3: What additional support, knowledge, or skills do teachers need to improve ICT use in their classrooms to positively impact student achievement in biology?

Review of the Literature

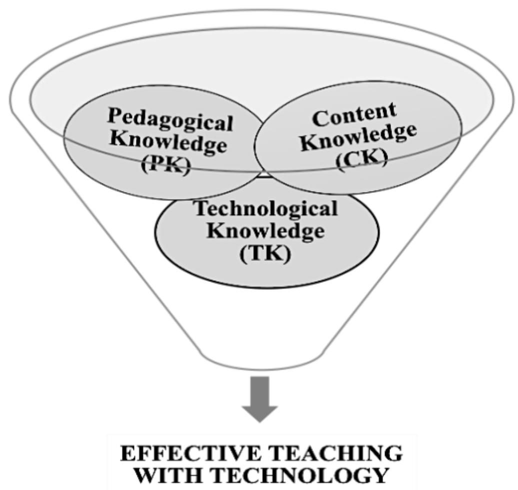
Conceptual Framework

This study's conceptual framework was Mishra and Koehler's (2006) technological pedagogical and content knowledge (TPACK) framework. The TPACK framework builds on Shulman's (1986) construct of pedagogical content knowledge (PCK) which highlighted the importance of teachers possessing content knowledge (CK) about what they teach and pedagogical knowledge (PK) about how to teach. In their seminal 2006 article, Mishra and Koehler noted the momentous changes in education from technology integration and created a new framework that added technological knowledge (TK) to PCK. The new framework was initially referred to as TPCK and later as TPACK. Mishra and Koehler proffered TPACK as the foundation of effective teaching with technology—requiring knowledge about content and epistemology, sound pedagogy, and information about technology affordances. Mishra and Koehler and Walsh (2017) emphasized that TK is not separate from PCK but is an integral part of how teachers use technology for content sharing and transforming their pedagogy. M. J. Koehler et al. (2013) and Ocak and Baran (2019) posited that the development of TPACK is critical to effective teaching with technology.

The TPACK framework comprises the three constructs of PK, TK, and CK (Mishra & Koehler, 2006). The framework emphasizes the interdependence and interwovenness of TK, PK and, CK (Mishra & Koehler, 2006; Willermark, 2018). The interaction of the three constructs provides the flexibility needed to successfully integrate technology into teaching (M. J. Koehler et al., 2013; Walsh, 2017). Figure 1 represents the TK, PK, and CK interaction for effective teaching with technology.

Figure 1

TPACK Interactions



Note. Adapted from "What is technological pedagogical content knowledge (TPACK)?" by Koehler, M. J., Mishra, P., & Cain, W. (2013). *Journal of Education*, *193*(3), 13–19.

Mucundanyi and Woodley (2021) noted the importance of TPACK in teachers' selection of technologies that support pedagogy and student learning. Mishra and Koehler (2006) suggested that lack of TPACK could keep technology as a separate construct, leading to problems with using technology in the classroom. For example, teachers might not keep up with the rapid rate of technology change (Mishra & Koehler, 2006) or prioritize technology interactions over student learning (Mishra & Koehler, 2006; Walsh, 2017). M. J. Koehler and Mishra (2009) cautioned that newer digital technologies, which are protean, unstable, and opaque, present new challenges to teachers who are struggling to use technology in their classrooms. M. J. Koehler and Mishra also noted that technologies are neither neutral nor unbiased, nor is it clear how the affordances and constraints of specific technologies influence what teachers do in their classrooms. It is important to consider contextual factors related to technology choice, as teachers operate in diverse contexts of teaching and learning (M. J. Koehler & Mishra, 2009). While advocating a need for modern teachers to employ modern tools to prepare modern students for a modernized future, Magana (2017) opined that teachers' consistent adoption of instructional practices with technology was tenuous.

TPACK has been widely accepted as a framework for effective technology integration into education but has been criticized for an impreciseness of the definitions for the different domains (Willermark, 2018). Magana (2017) and Wang (2018) posited that TPACK lacks a clear pathway for teachers to measure their TK attainment and for administrators to evaluate teachers' TK accurately. Ocak and Baran (2019) noted that there is a paucity of information on the indicators of teachers' TPACK in science classrooms. A practical and measurable framework on what effective technology integration looks like appears to still be needed (Kolb, 2017).

Nevertheless, I selected the TPACK framework to ground the current study because its concepts aligned with the study's problem and purpose. I used the TPACK framework to contextualize the current study as I explored local biology teachers' ICT integration into their classrooms. I applied the TPACK framework to the current study's data collection process by incorporating elements of TPACK into developing the interview questions (IQs). I also applied constructs of TPACK as I coded data from participant interviews. The TPACK framework may help me find different ways to redress the current study's social problem, that of local teachers' struggling to integrate ICT into their biology classrooms effectively.

Literature Search

After identifying a relevant and significant topic, I embarked on a literature review to situate the current study among the existing research (Laureate Education, 2012). Ravitch and Carl (2016) noted the importance of the literature review in tracing the etiology of specific fields related to a study, identifying central theories, guiding research questions, and identifying methodologies employed in studying related or overlapping topics. Searching the existing literature about ICT in education helped me decide that my interest in exploring local teachers' experiences with integrating ICT into the high school biology curriculum might be research worthy and significant. I was able to situate the local problem within the broader problem of ICT integration into educational curricula to impact students' achievement.

To establish a clear direction for the literature search after selecting a conceptual framework to underpin this qualitative study, I needed to delineate some focus areas. The chosen areas of focus were (a) benefits of ICT integration into educational curricula, (b) initiatives for ICT integration into educational curricula, (c) ICT integration into science curricula, (d) ICT challenges for schools, (e) mitigating challenges to ICT integration into educational curricula, and (f) ICT integration best tactics for classrooms. The areas of focus aligned with the study's purpose of exploring biology teachers' ICT integration into their classrooms.

Educational Benefits of Information and Communications Technology

ICT integration into educational curricula has been suggested as a way to improve students' performance in many subject areas due to its potential to address diverse learning styles, boost student motivation and engagement, and promote students' self-construction of knowledge (McKnight et al., 2016; Naji, 2017; Sargent, 2017). McKnight et al. (2016) proffered that ICT transforms learning routines through affordances such as improving information access, extending purpose and audience for student work, and restructuring teacher time. ICT in educational settings also fosters the development of skills of collaboration, student inquiry, and creativity, leading to new methods of assessing student learning that incorporate the skills (Gonzalez, 2020).

ICT is redefining classrooms and changing the face of education globally (The World Bank, 2020a). ICT in the classroom affords opportunities for teachers to transform instructional quality and demand higher order thinking skills from students (Alemu, 2017; Astuti et al., 2020). Petko et al. (2017) noted that positive attitudes toward educational technology were associated with higher test scores in a large number of countries. ICT facilitates the transformation of classrooms from teacher-centered to learner-centered, where active participation and lifelong learning occur (Yilmaz, 2017).

However, Alemu (2017), Hutchison (2018), and Parong and Mayer (2021) cautioned that ICT does not automatically add quality, relevance, and accessibility to teaching and learning because it can assume trivial and distractive purposes. Hite et al. (2019), Makransky et al. (2019), and Whittier (2016) also refuted the reputed benefits of ICT integration into curricula. Whittier cautioned against unquestioning acceptance of the constructive approaches to educational technology use and alluded to the positive contributions that traditional didactic instruction can make to student learning. Whittier's study showed that students who completed assigned technology learning tasks independently showed significantly more superficial and lower level knowledge than students who received the teacher modeling to complete the assignments. Bai et al. (2016) in their studies on ICT integration into education raised critical discussion points about the ICT types and the level of use that affect student achievement. Webster (2017) challenged assumptions about ICT integration into curricula, such as its inevitability and the need to embrace it or be left behind. Webster maintained that technology does not supersede pedagogy and highlighted the risks of integrating ICT without sound pedagogy and alignment of the implementation with educational goals and curricula.

Students have demonstrated underachievement in biology globally at different educational levels (Reece & Butler, 2017; Shaheen & Khatoon, 2017). Reece and Butler's (2017) research at the college level revealed an above-average number of students earning failing grades in Introductory Biology, seemingly due to a lack of motivation to complete the course. Findings from research on integrating ICT into biology curricula to improve students' biology performance have yielded mixed results (Reece & Butler, 2017; Shaheen & Khatoon, 2017; Xiong, 2018). Shaheen and Khatoon (2017) compared pretest and posttest scores for ninth-grade biology students in two schools in Pakistan. Teachers in the study presented a traditional biology lesson module followed by an ICT-enriched biology lesson module. Findings showed significant improvements in posttest means for the students, suggesting positive improvements from

ICT integration into biology curricula. Xiong's (2018) dissertation revealed that the use of innovative technology positively impacted students' learning of biology content and motivated a more in-depth exploration of biology concepts. Conversely, Reece and Butler (2017) reported no improvements in students' performance or motivation to learn biology after exposure to ICT-enriched laboratory courses.

Information and Communications Technology Integration Initiatives

The adoption and effective use of ICT for teaching and learning is an often-discussed issue in contemporary education policymaking processes (Baturay et al., 2017). Substantiated reported benefits from ICT integration into many curricula have advanced education reform, for example, through curriculum revisions and shifts in pedagogy (Alemu, 2017; Piper et al., 2017). Especially for developing countries, effective ICT integration is significant in improving the quality of education (Basargekar & Singhavi, 2017; Piper et al., 2017). Governments of many countries have accepted the claims that ICT improves education, consequently investing intensively in ICT for teaching and learning (Dintoe, 2018; Ergado, 2019; McKenzie, 2019; Piper et al., 2017). The onset of the COVID-19 pandemic has spurred unprecedented growth in ICT integration into teaching and learning (The World Bank, 2020a). For many countries, ICT-facilitated instruction was the only way to provide students an education amid the disruptions of the COVID-19 pandemic (Kara, 2021; The World Bank, 2020a).

However, ICT integration efforts have not all been positive (Dintoe, 2018; Ergado, 2019; Piper et al., 2017; Steiner & Mendelovitch, 2017). Although Piper et al. (2017) purported enhanced learning outcomes from the integration of a National Tablets

Program across primary schools in Kenya, Ergado (2019) reported that ICT integration into higher education in Ethiopia was inadequate because of the absence of a clear ICT policy and the lack of training for instructors. Dintoe (2018) described ICT integration at the University of Botswana in South Africa as mostly teacher centered, which defeated the intent of the constructivist approach to ICT integration outlined by Whittier (2016). Findings from a study in Israel indicated that science teachers used ICT primarily for visual aspects of their teaching, such as upgrading classroom demonstrations (Steiner & Mendelovitch, 2017). In their study, Steiner and Mendelovitch (2017) noted that most teachers were unaware of any necessity to change their teaching methods, and the minority who felt the need did not know how to achieve the end. Kara (2021) noted that ICT-facilitated instruction was not as successful as hoped.

Alemu (2017) and Hutchison (2018) cautioned that it is possible to use ICT for trivial purposes, to waste instructional time, and for destructive purposes. Serdyukov (2017) posited that despite progressive shifts in the integration of ICT in educational curricula, it is still unclear how to integrate technology into struggling schools effectively. Questions remain unanswered about how and to what extent teachers use ICT in their classrooms and the ways ICT is used to enhance instructional practices (Gerencer & Hayes, 2020; Maharaj-Sharma et al., 2017; Serdyukov, 2017).

The extent of teachers' adoption and integration of ICT into curricula is varied, with ICT tools being used mostly for low-value tasks, such as enhancing classroom lectures, rather than for high-value tasks such as promoting higher order thinking skills (Magana, 2017; Maharaj-Sharma et al., 2017; Steiner & Mendelovitch, 2017). Magana

(2017) reiterated that the potential for ICT to transform instructional practices is untapped and argued that despite much expenditure for technology in classrooms, there had been little substantive change to teaching and learning from the technology integration. Other researchers found that large-scale educational technology interventions showed only modest improvements in student achievement (Hite et al., 2019; Makransky et al., 2019; Parong & Mayer, 2018; Piper et al., 2017). Reasons varied from infrastructural issues (Al Ghazali, 2020) to lack of student engagement and motivation (Al Ghazali, 2020; Gerencer & Hayes, 2020) to lack of teachers' TK (Al Ghazali, 2020; Sumer et al., 2021).

Information and Communications Technology in Science Classrooms

The literature search I conducted yielded several instances of ICT integration efforts into primary through college classrooms to facilitate students' science learning through the creation of student-centered, student-directed, collaborative learning environments (Alt, 2018; Hutchison, 2018). "Flipping" science classrooms, or introducing ICT into science instructional practices, has been proposed to facilitate hands-on activities and provide precise scaffolding for students who are learning science (Kavanagh et al., 2017). However, Bogusevschi et al. (2020) noted low university enrolment rates for science, technology, engineering, and mathematics (STEM) programs. Terrazas-Arellanes et al. (2017) suggested that quality science curricula and effective technology practices could help all students learn science and encourage interest in STEM careers.

New research confirms and extends the corpus of knowledge about ICT in science classrooms. Virtual Reality/Augmented Reality (VR/AR) has emerged as a classroom technology for achieving student-centered and student-directed science learning environments (Astuti et al., 2020; Bogusevschi et al., 2020; Parong & Mayer, 2021). VR/AR provides immersive experiences in real or simulated environments (Astuti et al., 2020; Bogusevschi et al., 2020; Parong & Mayer, 2021). The technology incorporates multimodal information in the form of written text, images, video, and audio and could be more effective in improving students' motivation to learn science and in improving their understanding of science concepts than written text alone (Sahin & Yilmaz, 2020). VR/AR also allows students to communicate in multiple ways the science concepts learned (Parong & Mayer, 2021). Virtual labs can be cheaper than setting up physical labs and maintaining them (Bogusevschi et al., 2020). Experiments can be run multiple times with no additional material costs, and run asynchronously (Bogusevschi et al.).

Researchers have reported improved student learning outcomes from VR/AR in science classrooms (Parong & Mayer, 2021; Sahin & Yilmaz, 2020). Bogusevschi et al. (2020) reported students' enhanced problem-solving skills, practical skills, and computer literacy from using virtual labs. Astuti et al. (2020) noted improvements in students' critical thinking skills, and curiosity and open-mindedness about science. Other researchers did not confirm the claims that VR/AR increased students' science performance (Hite et al., 2019; Makransky et al., 2019). In their study on Immersive Virtual Reality (IVR) Parong and Mayer (2021) noted that virtual environments could be distracting because of their novelty, thus reducing student learning.

Apart from the distractive possibilities of VR/AR, a factor that might limit its use in education is the required training for instructors to implement the technology in their classrooms effectively (Kavanagh et al., 2017). Nevertheless, VR/AR appears promising for science learning and could elevate ICT use in science classrooms (Parong & Mayer, 2021). Particularly for students engaged in remote learning, VR can enable scientific experimentation in the absence of physical laboratories (Guzmán & Joseph, 2021; Nasr, 2020; Parong & Mayer, 2021; Wright, 2020). Parong and Mayer opined that in the near future, IVR's novelty will diminish and using that technology will become as familiar as learning with other multimedia technologies.

Information and Communications Technology Challenges for Schools

Particularly for developing countries, ICT integration into education appears to be challenging, and often inadequate (Plummer et al., 2021; The World Bank, 2020b). Earlier research in Ethiopia showed that limited infrastructure, lack of skilled human resources, management support, and a clear ICT policy for pedagogical practices negatively impacted ICT integration into that country's education system (Ergado, 2019). In Indonesia, science teachers cited several challenges to ICT integration into their classrooms, including time restraints, large class sizes, lack of teachers' technological skills and experience, and lack of equipment and facilities (Effendi-Hasibuan et al., 2019). Although ICT was available and accessible at the University of Botswana, faculty found it challenging to use the technology due to administrator's reportedly primary focus on student outcomes with little concern for teacher challenges related to the integration (Dintoe, 2018). The result was that most of the university's faculty used a teacher-centered rather than a learner-centered approach for instruction (Dintoe, 2018).

Other researchers highlighted infrastructural/technical issues, such as inadequate access to ICT resources, and lack of technical support, that prevented the integration of ICT into teaching and learning (Alemu, 2017; Al Ghazali, 2020; Fletcher & Nicholas, 2018; Strauss, 2020; Withers et al., 2021). A lack of teachers' motivation, desire, and confidence in trying new tools could also present challenges for integration of ICT into curricula (Binmubarak Aljuzayri et al., 2017; Serdyukov, 2017). A lack of teachers' TK has also been reported as a challenge (Al Ghazali, 2020; Sumer et al., 2021).

Research on ICT integration into primary through high school classrooms showed that the integration appeared inadequate (Fletcher & Nicholas, 2018; Jurica & Webb, 2016; Magana, 2017). Jurica and Webb's (2016) survey of technology use in K-12 classrooms in Texas showed that only 25% of teachers reported that their students used technology for 20 minutes or more during the school day. Jurica and Webb recommended further research to determine what teacher preparation programs and school district support could help teachers effectively integrate technology into their classrooms. Fletcher and Nicholas (2018) reported a wide variation in digital technology use among the schools they surveyed and attributed the variance to inequalities in technology access.

Mitigating Information and Communications Technology Challenges

The existing literature contains many recommendations for mitigating challenges to ICT integration into educational curricula. The recommendations range from changes in pedagogical practices (Sumer et al., 2021; Zyad, 2016), to infrastructural adjustments (Al Ghazali, 2020; Laronde et al., 2017; Withers et al., 2021), to amendments in government policies (Al Ghazali, 2020; Laronde et al., 2017; Withers et al., 2021).

Changes in institutional pedagogical practices, such as reducing class size and increasing instructional time with students, may encourage teachers to integrate ICT into their classrooms (Zyad, 2016). Fletcher and Nicholas (2018), Kavanagh et al., (2017), and Zyad (2016) highlighted challenges of inadequate ICT equipment and high ICT costs. Nwankwo and Njoku (2020) suggested that financial challenges to ICT use could be resolved by seeking public–private partnerships that may provide the critical infrastructure needed in schools. Laronde et al. (2017) emphasized that increased investments by government and school boards in ICT for education could enhance teachers' use of ICT in their classrooms. Supportive school and government policies could also positively impact teachers' perceived ability to use ICT in their classrooms (Basargekar & Singhavi, 2017).

The provision of ICT PD opportunities for teachers is a recommendation that addresses intrinsic teacher factors related to ICT use in their classrooms, such as resistance to change, lack of ICT-related skills, or unwillingness to try new teaching methods (Asensio-Pérez et al., 2017; Basargekar & Singhavi, 2017; Serdyukov, 2017). PD workshops on ICT integration into classrooms can enhance teachers' TPACK and influence them to transform their teaching (Alemdag et al., 2020; Mishra et al., 2019). However, PD for teachers should relate specifically to the teachers' learning needs and the available technologies (Kavanagh et al., 2017; Powell & Bodur, 2019). PD should be pedagogically sound and provide instructors with sufficient support and time to grasp the new technologies (Alemu, 2017; Pombo et al., 2017). Ineffective ICT PD leads to teachers' inability to transform classrooms into student-centered foci (Sharick, 2016).

When confronted with challenges and where solutions do not appear imminent, teachers often reverted to traditional instructional methodologies (Maharaj-Sharma et al., 2017).

It is not easy to spread innovation across schools (Magana, 2017; Maharaj-Sharma et al., 2017; Serdyukov, 2017; Stowell et al., 2018). Teachers and school administrators are often cautious about a looming change and can be intolerant about the uncertainties caused by innovations (Serdyukov, 2017). Clear guidelines for selecting and using ICT for instruction and assessment are needed (Magana, 2017; Maharaj-Sharma et al., 2017). Syllabi must contain clear ICT policies and identify situations where ICT can be applied (Magana, 2017; Stowell et al., 2018). Nwankwo and Njoku (2020) alluded to the importance of including local content in the new syllabi to enhance knowledge and skill acquisition.

Integrating Information and Communications Technology Best Tactics

ICT is integral to the functioning of modern schools, and critically so during the current COVID-19 pandemic where most schools transitioned to technology mediated virtual teaching and learning (The World Bank 2020a). However, not every technology adoption effort nor learning management system (LMS) worked smoothly (Kara, 2021; The World Bank 2020a). A clear direction for meeting students' learning needs during the COVID-19 pandemic is uncertain (N. Johnson et al., 2020).

Despite challenges with inadequate networks, unreliable devices, unworkable policies, and erroneous practices, there are recommended best practices that could make the ICT integration easier. Crittenden et al. (2019) recommended that teachers adopt a vital new role of modeling technology use so that their students can develop skills of inquiry, critical thinking, and creativity in interacting with technology. New researchers in the field of online learning recommend technology training to equip teachers to integrate ICT effectively (Al Ghazali, 2020; Bozkurt et al., 2020; Nasr, 2020; Sumer et al., 2021). Governments that are responsible for public educational institutions can incorporate public–private partnerships to build the critical infrastructure needed for effective technology integration (Nwankwo & Njoku, 2020). Teachers should be allowed input into building local curricula content to enhance knowledge and skill acquisition (Nwankwo & Njoku, 2020). With proper support, ICT can be integrated in educational contexts innovatively (Basargekar & Singhavi, 2017; Laronde et al., 2017; Nwankwo & Njoku, 2020; Pombo et al., 2017).

Effective integration of ICT into education is more than having the required hardware or software or having teachers with the technological skill to implement the technology (Bozkurt et al., 2020; Saxena, 2017). Sound pedagogies on teaching and learning must ground the adoption of ICT in classrooms (Heitink et al., 2017; Hutchison, 2018; Kavanagh et al., 2017; Sumer et al., 2021). Heitink et al. (2017) showed that the highest level of ICT use occurred with the support of pedagogical practices that promote activation of student learning. Saxena (2017) purported that effective ICT integration required a conjunction between curricular content, teacher knowledge, well-matched theoretical frameworks, and appropriate pedagogy. Sumer et al., recommended that teachers learn the pedagogical differences between FTF and online instruction to avoid transferring FTF teaching habits to the drastically different online learning arena.

Implications

The topic for the current study arose from the problem of biology teachers experiencing challenges integrating ICT into the biology curriculum in a Bahamian public high school. Positive social change may develop from the study. The study’s data could identify specific areas of need regarding improving ICT use in local biology classrooms. Addressing those needs could help increase ICT use and improve student biology achievement in Bahamian schools. The current study’s findings could lead to amendments to teaching and learning practices related to delivering the biology curriculum in Bahamian schools.

A few project deliverables could emerge from the current study. One possible project deliverable could be creating a PD workshop to provide support to biology teachers in Bahamian schools on how to integrate ICT into a specific biology curriculum area, such as the coursework. Coursework is the practical hands-on component of the biology syllabus taught in Bahamian high schools. Coursework is used for formative assessment but impacts the summative evaluation of the students. By performing a selection of experiments at different skill levels, students gain practical experience about how scientists make hypotheses, make observations or measurements, record and process data, plan and carry out investigations to test hypotheses, and make inferences. According to teacher reports, biology coursework can be challenging, for example locating needed apparatuses and scheduling time for students to perform several in-laboratory experiments. According to teacher reports from the current study, coursework has become even more challenging during the COVID-19 pandemic, where physical laboratories are inaccessible.

However, ICT allows easy accessibility to scientific information, activities, and virtual labs (Alt, 2018; Chandrasekaran, 2020; Tsichouridis et al., 2019). A PD workshop could help teachers learn how to use virtual labs and virtual data for teaching scientific skills in their virtual biology classrooms (Chandrasekaran, 2020; Wright, 2020.). Knowledge and skills acquired by the teachers could improve teachers' TPACK and enable them to guide their students in obtaining maximum benefits from this practical component of the biology syllabus.

The development of a position paper is another possible project direction for the current study. N. Johnson et al. (2020) recommended that countries develop sustainable education plans that can withstand the challenges of the COVID-19 pandemic. A position paper could support that recommendation. In developing a position paper, I would include the recommendations obtained from teachers in the current study for improving teaching and learning with technology. Curriculum developers could gain insights aligning ICT implementation with educational goals from the current study's participants' experiences integrating ICT into their classrooms (see Karadeniz & Thompson, 2018; Webster, 2017). Educational policymakers, school administrators, and school boards in the Bahamian setting might be better informed about local teachers' needs for effective teaching with technology.

Summary

Section 1 of my project study's manuscript included the study's purpose, which was to explore ICT integration into the biology curriculum by teachers in Bahamian public high schools. I defined scholarly terms related to the study. The study's significance for informing effective ICT integration into the Bahamian public high school biology curriculum and potentially influencing policy decisions on ICT integration into local schools was also outlined in this section. The RQs were also itemized in this section. The three RQs related to the study's problem and purpose, and also aligned with the conceptual framework. TPACK is the conceptual framework underpinning the study.

In Section 1, I addressed the problem of biology teachers struggling to properly integrate ICT into their Bahamian public high school classrooms to deliver the biology curriculum to their students. Sources cited from the literature review, such as Alemu (2017), and Naji (2017), highlighted the benefits of integrating ICT into 21st classrooms to enhance teaching and learning. I also referred to the initiatives for ICT adoption into education by many countries before and during the COVID-19 pandemic (see Dintoe, 2018; Ergado, 2019; McKenzie, 2019; Piper et al., 2017; The World Bank, 2020a).

I identified challenges to ICT integration into curricula from the existing literature. I noted the challenges of limited ICT infrastructure (Al Ghazali, 2020; Effendi-Hasibuan et al., 2019; Withers et al., 2021) and teachers' sometimes-limited technology skills (Sumer et al., 2021). I discussed recommendations from the existing literature for mitigating challenges of ICT integration into curricula including providing adequate ICT tools and supportive infrastructure (Al Ghazali, 2020; Strauss, 2020), providing PD opportunities in ICT use (A. Koehler & Farmer, 2020; Sumer et al., 2021), and the creation of clear policies for the ICT integration (Al Ghazali, 2020; Withers et al., 2021).

In Section 2 I provide information on the current study's methodology. I explain my reasons for choosing qualitative methodology for the study. I identify criteria for selecting the study's participants and discuss strategies for ensuring confidentiality. I detail the data collection and data analysis processes for the study and identify strategies for building the study's validity. I present the findings from the current study and clearly outline the "paper trail" leading to the findings. Finally in Section 2, I identify the project deliverable developed from the study's results.

In Section 3, I present the project deliverable and justify its selection. I discuss my plan for implementing the project and itemize needed resources and existing supports, and potential barriers and solutions. I also present my plan for evaluating the successful implementation of the project and its implications for social change.

In Section 4, I reflect on the project's strengths and limitations, describe alternate approaches and solutions, and proffer directions for future research related to my study's problem and purpose. I reiterate the implications for positive social change that may be afforded by the project deliverable. I present the current study's conclusions and reflect on personal growth as a scholar, practitioner, and project developer as important outcomes from completing Walden University's educational doctoral program.

Section 2: The Methodology

Egbert and Sanden (2014) defined *methodology* as a reasonable plan for gathering and analyzing information that responds to a line of research inquiry. The research questions, conceptual framework, contextual influences, existing theory, and researchers' epistemological leanings and beliefs guide a study's methodology (Ravitch & Carl, 2016). I selected qualitative methodology for exploring the problem of local public high school biology teachers experiencing challenges integrating ICT into their biology classrooms. The initial plan was to gather narrative data to answer the RQs from in-person, in-depth interviews of purposefully selected biology teachers. However, the COVID-19 pandemic resulted in social distancing mandates and closed educational institutions. Instead of in-depth in-person interviews in physical classrooms, I collected data virtually from in-depth online interviews with the current study's participants. The data were analyzed to answer the study's RQs by applying constructs of TPACK, a framework for effective technology integration into education that underpinned the current study (see M. J. Koehler & Mishra, 2009; Mishra & Koehler, 2006).

Research Design and Approach

I selected qualitative rather than quantitative research methodology for this current study for several reasons. I wanted to *talk* with the teachers, I wanted to *hear* about their experiences and viewpoints and not just collect survey data (see Rubin & Rubin, 2012). My plan to interview teachers to learn about their experiences with integrating ICT into their classrooms aligned with the exploratory design of qualitative research methodologies (see Leedy & Ormrod, 2010; Peterson, 2019; Ravitch & Carl, 2016). I expected qualitative design to allow an inductive analysis of the narrative or textual data shared by the participants (see Burkholder et al., 2016; Peterson, 2019; Rubin & Rubin, 2012; Yin, 2016). Also, qualitative research methodologies allow insight into the context of participants' experiences and how they make meaning of those experiences (see Carminati, 2018; Peterson, 2019; Ravitch & Carl, 2016; Yin, 2016).

The current study was expected to have a small number of participants because there are not many biology teachers in the local setting. A small participant pool proscribed quantitative methodology, but allowed a qualitative approach that usually involves small participant numbers and large amounts of narrative data (see Leedy & Ormrod, 2010; Peterson, 2019; Ravitch & Carl, 2016; Shenton, 2004). Findings from qualitative studies are often not generalizable because of the subjective analysis of data, but can provide insights than can be applied to other locations (Leedy & Ormrod, 2010; Peterson, 2019; Ravitch & Carl, 2016; Shenton, 2004). Conversely, quantitative studies are typically associated with large numbers of participants and produce numerical data for statistical and objective analyses leading to the deduction of generalizable findings (Lambert, 2012; Ravitch & Carl, 2016). However, qualitative research does not involve a less thorough approach or less credible findings than quantitative research (Carminati, 2018). Contextual or phronetic knowledge from qualitative studies is as fundamental as epistemological knowledge from quantitative studies (Carminati, 2018). The current qualitative exploration of teachers' ICT integration into their local biology classrooms could add contextual knowledge about ICT integration into educational curricula to impact students' achievement, as alluded to by Carminati (2018).

In choosing the most appropriate research design for the study, I considered several options within the qualitative paradigm. A qualitative case study approach was contemplated but rejected. Case studies, as described by Egbert and Sanden (2014) and Leedy and Ormrod (2010), constitute a single bounded system with participants experiencing similar experiences. My study's setting did not meet these criteria. Case study approaches also emphasize data collection through observations, interviews, and document and archival reviews (Ravitch & Carl, 2016; Stake, 2005; Yin, 2016). Triangulation among the several forms of data occurs to reduce the likelihood of misinterpretation (Ravitch & Carl, 2016; Stake, 2005; Yin, 2016). The simple qualitative design selected for the current study included multiple data sources from online contacts with interviewees, and involved investigator triangulation, peer scrutiny, and participant validation (see DeCino & Waalkes, 2019; Ravitch & Carl, 2016; Yin, 2016.

A grounded theory approach was also rejected. The grounded theory design involves processes such as coding, memo writing, theoretical sampling, and theoretical saturation that are involved in the qualitative approach (Ravitch & Carl, 2016; Yin, 2016). However, data analysis occurs throughout the overall research design in the grounded theory approach (Lichtman, 2011). Data analysis for the current study was conducted during and after completion of data collection and not as part of the overall research design. As described by Leedy and Ormrod (2010), a content analysis methodology also involves systematic and detailed data analyses. However, I rejected this methodology because its approach is more suited to analyzing forms of human communication (Leedy & Ormrod, 2010). Finally, I rejected an ethnographic approach that has a cultural focus, as described by Leedy and Ormrod (2010), Ravitch and Carl (2016), Thomas (2013), and Yin (2016). The current study did not have a cultural focus.

Participants

In this section, I discuss participant selection, my procedures for gaining access to participants, and how I protected participants' rights including confidentiality. I also discuss my researcher role and how I reduced researcher bias in the data collection and analysis phases of the current study.

Participant Selection

The purpose of this current qualitative study in a local Bahamian setting was to explore teachers' ICT integration into the public high school biology curriculum. I proposed a purposefully selected sample size between 10 and 12 biology teachers from five Bahamian public high schools who integrated ICT into the delivery of the biology curriculum in FTF classrooms. I excluded biology teachers who had not used ICT in their classrooms for teaching or grading practices because they did not meet the selection criteria for this study. I expected a purposeful sampling strategy to provide context-rich cases and enough participants to enable data saturation, a situation in which no new information and no new themes emerge from data collection and analysis (see J. L. Johnson et al., 2020; Lambert, 2012; Ravitch & Carl, 2016; Yin, 2016). The number of participants, though small, was expected to generate sufficient rich, thick narrative data for reliable inductive analysis (see Francis et al., 2010; Rubin & Rubin, 2012; Yin, 2016). Using more than one study site increased the volume and distribution of data that could lead to the credibility of findings (see Carminati, 2018).

Justification for Number of Participants

I proposed a participant pool of 10–12 biology teachers for the current study. The proposed number of participants was justified by the number of biology teachers in the five schools targeted as study sites. A total of 27 biology teachers were employed in the schools, where the instructional mode was virtual and blended. A sample size between 10 and 12 participants from the five schools was expected to provide enough data to address the current study's research questions and enable data saturation (see Francis et al., 2010; Rubin & Rubin, 2012; Yin, 2016). I ended up with eight participants.

It is challenging to accurately predict a large enough sample size to generate sufficient quality data for reliable inductive analysis or to determine data saturation (J. L. Johnson et al., 2020). Nevertheless, I concluded that with the eight interviews, I reached data saturation for the current study. Many responses from participants were quite similar, in particular those of P2, P3, P4, and P5 from School B. In my researcher journal, I reflected that by the time I coded P5's interview, I had noticed the similarities with the responses from P2, P3, and P4. I confirmed data saturation after coding the interview from P6. P6's responses were quite similar to those of previous participants, and no new codes or themes emerged from coding interviews from P7 and P8. Code occurrences also helped to determine data saturation. For example, the codes of familiarity, student engagement, relevant PD/training, and unified government–teacher technology policy/plan were mentioned by P1–P5 and later by P6–P8.

Procedures for Gaining Access to Participants

After receiving IRB approval to conduct the current study (approval #04-28-21-0535515), I hand-delivered letters to the principals or gatekeepers of five public high schools in the Bahamas requesting their cooperation with recruiting participants for my research. First, I requested the principals' cooperation with distributing recruitment flyers to the biology teachers in their school. Additionally, I asked principals to share the biology teachers' names and professional email addresses with me to send email invitations to teachers to participate in the study. I informed each principal that agreeing to the latter request would require signing a letter of cooperation in compliance with Walden University's IRB guidelines. I obtained signed letters of cooperation from three principals and submitted them to Walden University's IRB. I later obtained the names and professional email addresses of the biology teachers employed at these three schools. Two principals refused to share biology teachers' contact information with me but agreed to distribute recruitment flyers to them.

I delivered recruitment flyers for distribution to biology teachers at each school and I sent invitation emails to the teachers whose email addresses were shared with me. I waited 2 weeks for responses on the Google informed consent form for which I had provided a link in the recruitment flyers and in the emails. I initially received only three positive responses from potential participants who met the current study's participation criteria. I emailed teachers again assuring them that their ICT integration experiences needed to be shared, would be shared confidentially, and would contribute to the corpus of information about ICT integration into virtual classrooms. I conducted the recruitment process between April 30, 2021, and May 31, 2021, at which time I recruited a total of eight participants for the current study.

Obtaining informed consent from potential participants was the next step in the study's data collection process. Lambert (2012), Ravitch and Carl (2016), Rubin and Rubin (2012), and Yin (2016) advised that researchers allow prospective participants to access and read an informed consent form before deciding to participate. The recruitment flyers and invitation emails included brief details of the study and a link that potential participants could click for more information. The link took them to a Google form where the first page was the informed consent where they were provided detailed information about the proposed research to make an informed decision about participating.

In the Google informed consent form, I indicated that participation in the study would be voluntary and without coercion. I informed potential participants that I would collect data from them through a one-on-one audio-recorded virtual interview lasting 45 to 60 minutes at a date and time of their convenience. I noted that I would ask them to read sections of their interview transcript to confirm the accuracy and provide commentary. Ravitch (2020) posited that people might be unable to participate in research because of a lack of access to the video-conferencing tool selected to facilitate the virtual interviews, discomfort with using the software, or other reasons related to the data collection methodology. Ravitch posited that if people "are unable to engage in research because their lives are turned upside down, their stories and anything built from the research excludes them" (p. 3). Therefore, to ensure equity of representation, I suggested Zoom as the video-conferencing software I would use to collect interview data but kept Skype in mind as an alternative.

Obtaining the potential participants' consent was necessary before I could initiate the data collection process. To indicate consent to participate in the study, potential participants inserted the words "I consent" at the bottom of the Google informed consent form, along with their name and school's name. Additionally, potential participants inserted a non-work-related email address or cellphone number, or both, and submitted the form. These actions signified active consent to participate in the study in place of the previously printed and physically signed consent forms recommended by Lambert (2012) and Rubin and Rubin (2012). People who did not wish to participate closed the form.

I selected the study's participant pool from the nine positive responses recorded on the Google informed consent form. Of these nine responses, two interested teachers did not meet one of the current study's criteria for the study. The two respondents were not high school biology teachers. Instead, they were general science teachers in junior schools. I emailed both teachers thanking them for their interest in the research and explaining why I could not include them. A tenth prospective participant responded by direct email to me, but I requested that she indicate consent on the Google informed consent form before data collection began. After she did this, I included her in the participant list.

The eight participants for the study taught biology in five Bahamian public high schools. I emailed each of the eight participants, thanking them for their willingness to participate in the study. I sent separate emails to each participant to not disclose the names or schools of the biology teachers who would participate in the study. I also requested a few dates and times from the participants regarding when they might be available for the virtual interview. After considering all interview dates and times to avoid duplications, I confirmed one of the suggested dates and times with each participant.

Establishing a Researcher–Participant Working Relationship

I had a previous collegial working relationship with some of the current study's participants, so it was easy to converse with them during the data collection process. Conversely, unfamiliarity between other participants and myself might have affected the close interviewer–interviewee rapport needed to generate the thick, rich data needed for this study (see Ravitch & Carl, 2016; Rubin & Rubin, 2012). I tried to make the interview sessions comfortable for all participants (see Ravitch, 2020; Rubin & Rubin, 2012). I spoke with interviewees on a one-on-one basis where no participant could feel intimidated by the presence of other participants. Before asking the interview questions, I followed Ravitch's (2020) recommendation to briefly discuss the coronavirus situation to establish empathy with participants and encourage them to share their feelings. I kept my webcam on during each interview so that interviewees could see me, although I gave them the option to have their cameras on or not. I attempted to maintain a conversational tone during the interviews to help participants share deeply, as advised by Rubin and Rubin (2012), Shenton (2004), and Yin (2016). By using the responsive interview approach recommended by Rubin and Rubin, I was able to create comfortable interaction between each participant and myself. However, I strove for *neutrality* throughout the interviews by being psychologically not too close but not too distant from the participants so that I did not influence their responses (see Rubin & Rubin, 2012; Yin, 2016).

Protection of Participants' Rights

Protecting the rights of human subjects is an ethical issue researchers must consider before, during, and after a research study (Burkholder et al., 2016; Lambert, 2012; Rubin & Rubin, 2012; Yin, 2016). Completing Walden University's Doctor of Education coursework and the Collaborative Institutional Training Initiative (CITI Program) equipped me with knowledge about conducting ethical research with human subjects. Therefore, I outlined the risks and benefits of participating in the current study in the informed consent Google form as recommended by Rubin and Rubin, Walden University's IRB, and Yin. I explained that participants could experience fatigue or stress during the virtual interviews but noted that these are minor discomforts experienced in daily life. I offered no reimbursements for participating in the study. I anticipated the teachers' altruism in contributing to the expansion of knowledge and practice about ICT integration into classrooms and informing policymakers about possible modifications for effective ICT integration into education.

I understood the potential risk for psychological harm if participants are misled, misinterpreted, or deceived at any part of my study (see J. L. Johnson et al., 2020), Walden University's IRB, and Yin (2016). Therefore, I was open about informing participants of what participation in the current study would involve. I explained to the study's participants that I would collect data using virtual one-on-one audio-recorded interviews and I would not video-record any interview. I informed the study's participants that I would transcribe and check their audio-recorded interviews and ask them to verify the accuracy and provide commentary on transcript sections.

New concerns about conducting research have arisen because of the coronavirus pandemic that began in 2019. Ravitch (2020) highlighted concerns about designing and conducting valid, humanizing research under social distancing conditions. Ravitch noted that there could be difficulties identifying and accessing participants and asking persons for time to do virtual interviews. Ravitch also alluded to privacy issues surrounding the virtual collection of data from the researcher and participant standpoints. Therefore, I asked participants to confirm their identity and school. I selected an isolated area in my home to conduct the interviewees and also asked participants to talk with me in a secluded location where they could be free from interruptions. I expected the enhanced privacy to encourage participants to share their experiences and viewpoints with me freely. I also advised participants that they could discontinue their participation at any time and without the need for an explanation, as advocated by Rubin and Rubin (2012), Ravitch and Carl (2016), and Shenton (2004). I respected participants' kindness in granting me time for our conversations by being in the Zoom space at the precise time agreed on and carefully ensuring interview sessions lasted no longer than the stated 60 minutes. I emphasized the current study's independent nature in the informed consent form and assured participants that I would use data collected during the study for research purposes only. In the following section, I discuss the measures I used to ensure confidentiality of the data collection process.

Confidentiality

Anonymity was not possible in my study because I knew participants' names, email addresses, and the schools where they were posted. I needed access to the email addresses or the phone numbers of potential participants to make mutual decisions about scheduling virtual interviews and also to be able to send summaries of the interview transcripts for member checking and participant validation (see Fusch et al., 2018; Ravitch & Carl, 2016). I needed to know the names of the participants to verify their identities during the virtual interviews. Information about each participant's place of employment helped me to know that participants were distributed across several schools, thus giving me a broader distribution of data for the current study.

Although the participants in the current study were not anonymous, I carefully ensured confidentiality according to recommendations from Ravitch and Carl (2016), Rubin and Rubin (2012), Walden University's IRB, and Yin (2016). Ravitch and Carl (2016) recommended that researchers collect independent data from participants. Thus, I conducted one-on-one virtual interviews rather than focus group interviews. I shared links to the virtual video-conferencing sessions with the relevant participant only, so that uninvited persons could not log on to the virtual interviews. To further ensure confidentiality, I assigned pseudonyms to each participant and study site, using a system devised by myself and decipherable only by me. Any references to participants during data analysis and the presentation of findings used the assigned pseudonyms. I informed participants that I would share a summary of the study's findings with their school administrators, but that their identity would not be detectable.

I stored all interview audio recordings, interview transcripts, and my researcher journal in a dedicated file on my password-protected computer and backed up the file in the cloud. I scanned my hand-written field notes and stored them in the same file. I will permanently delete the file after five years. The hand-written filed notes are stored in a locked file cabinet in my home. After five years, I will shred and discard them.

Data Collection

In this section I briefly participant recruitment and emphasize the development of the current study's data collection instrument and the data collection process. I discuss my researcher role and procedures for dealing with discrepant data.

After obtaining IRB approval for the current qualitative study on ICT integration into Bahamian public high school biology classrooms I began recruiting biology teachers in five Bahamian public high schools. I obtained eight potential participants. I assigned pseudonyms to the biology teachers and their schools and collected data from the teachers between May 11, 2021, and June 7, 2021, during the COVID-19 pandemic. At the time of data collection, the eight participants, who had previously integrated ICT in classrooms, were involved in using ICT in virtual and blended classrooms.

Data Collection Instrument

I developed an interview protocol to explore the local teachers' ICT integration into the high school biology curriculum. An interview protocol is a broad line of inquiry covering the issues a study will explore and including possible questions and probes to elicit detailed information (Thomas, 2013; Yin, 2016). Interview protocols develop around a study's topic with the intentional design to answer the research questions (Yin, 2016). An interview protocol serves as a mental framework for the researcher during the data collection process (Yin, 2016). However, an interview protocol is not a rigid instrument (Yin, 2016). Instead, the interview protocol is a guide to data collection that is adjusted during use as the researcher learns when to shift topics and when to ask unscripted questions to prompt new revelations (Yin, 2016).

The interview protocol for the current study consisted of flexible semistructured questions (see Appendix D), as recommended by Rubin and Rubin (2012), Thomas (2013), and Yin (2016). The questions were open ended to allow participants to respond from their particular frames of reference (see Burkholder et al., 2016; Ravitch & Carl, 2016). I also included prompts that I would interject as needed to encourage interviewees to expand on their responses (see Yin, 2016). I aligned the interview protocol with the study's conceptual framework so that I could ascertain how TPACK underpinned the teachers' ICT use in their biology classrooms. Interview questions were aligned with the research questions as suggested by Castillo-Montoya (2016). Table 2 shows the alignment between the RQs and the IQs.

Table 2

Interview Protocol Matrix: Aligning IQs and RQs

Research question	Interview question
1. How do local public high school teachers decide to use ICT in their classrooms to deliver the biology curriculum?	1, 2, 3
2. What challenges do local public high school biology teachers experience in their integration of ICT into their biology classrooms?	4, 5
3. What additional support, knowledge, or skills do teachers need to improve ICT use in their classrooms to positively impact student achievement in biology?	6, 7, 8

I revised the study's interview protocol several times, especially after complying with the recommendation of my doctoral committee's chair to conduct two practice interviews with non-participants in my study. In my researcher journal, I reflected that the practice interviews were useful in helping me learn to listen to the interviewees and to be careful to not interrupt them as they spoke. I also made reflections after the actual interviews and adjusted or added prompts for subsequent interviews to gain the detailed and specific information that I needed to address the study's RQs adequately. Using the interview protocol and adjusting it during the virtual conversations helped ensure that I collected data anchored in the study's purpose and pertinent to the RQs (see Castillo-Montoya, 2016).

Interviews

I developed a brief script to introduce the online interviews (see Ravitch, 2020). I also began each interview session with a preamble during which I asked interviewees to share a little about their teaching careers and the impact of the C0VID-19 pandemic on their lives. I designed the preamble to help put participants at ease and allow them to divulge detailed information during the interview (see Ravitch, 2020). As I proceeded with the actual interview questions I judiciously interjected prompts to encourage the interviewees to elaborate on information that they believed to be important to the study (see Burkholder et al., 2016; Lambert, 2012; Yin, 2016).

Because of COVID-19 social restrictions, in-person interviewing was not an option as a data collection instrument for the current study. Instead, I interviewed the eight participants virtually on Zoom in 26-44 minute sessions. I audio-recorded the interviews on Zoom and doubly ensured the saving of the conversations by recording them also on QuickTime Player. I stored the audio recordings in MP4 format on my password-protected computer and in the cloud. In the informed consent form I assured participants that I would audio-record only, so I did not video-record any interview.

In addition to facilitating the virtual interviews, Zoom's video-recording capabilities allowed me to hear each participant and see those who chose to have their webcams on, thus enabling me to receive visual nuances of some conversations. At the start of interviews, I reminded participants that they had authorized audio-recording by indicating their consent to participate in the research on the informed consent form. I notified each participant when I started audio-recording. At the end of the interviews, I thanked each participant for granting me the time to talk with me and sharing valuable data for my study.

Researcher Role

I am a retired biology and marine biology teacher who previously taught at one of the study sites selected for the current study. Like the participants in the current study, I integrated ICT into my FTF biology classroom. Although I had a collegial working relationship with some biology teachers, my past employment did not create a conflict with my researcher role because I did not hold a supervisory position over other biology teachers. As the primary research instrument in this qualitative study, my crucial researcher roles included recruiting and selecting the study's participants, crafting the data collection instrument, conducting the virtual interviews, collecting and collating the data, and inductively analyzing the data. I assumed these roles while striving to reduce researcher bias and building objectivity to establish the study's validity.

Researcher Bias in the Data Collection Process

According to Fusch et al. (2018), qualitative methodology is often used to address social change, but qualitative researchers struggle with concepts of objectivity, truth, and validity. Bias is frequent in qualitative research, from the methods and methodology to the data collection and data analysis processes (Fusch et al., 2018; J. L. Johnson et al., 2020; Ravitch & Carl, 2016; Shenton, 2004; Yin, 2016). Yin (2016) noted the impossibility of completely removing bias and achieving true neutrality in qualitative studies. However, my acknowledgment of bias, and more importantly, my efforts at mitigating bias helped build validity of the current study, as advised by Fusch et al. (2018), Peterson (2019), Shenton (2004), and Yin (2016).

Lambert (2012), and J. L. Johnson et al. (2020) posited that similar contextual experiences with participants could help researchers with "fitting in" to their studies. Many of my ICT integration experiences were similar to those reported by the study's participants and this helped me to relate to this current study from an insider position. However, Lambert (2012), and Thomas (2013) cautioned that the similar contextual experiences could introduce bias into the study as there might be conscious and unconscious leanings toward participant responses. I acquiesced with my committee's advice about asking non-leading questions, and made every effort to maintain an open mind throughout the interviews. Yin posited that maintaining an open mind is equally as important as asking the right questions of participants in qualitative data collection.

Purposeful selection of participants for the current study involved bias (see J. L. Johnson et al., 2020; Shenton, 2004). However, as posited by J. L. Johnson et al., purposeful sampling provides the most appropriate participants in the most appropriate context for answering a study’s research question, and informed participants are more likely to contribute relevant data than the uninformed. The interview protocol that I used as a guide to data collection also involved bias, as alluded to by Yin (2016). My values, expectations, and perspectives were intricately interwoven into the interview protocol (see Yin, 2016). Additionally, my positionality, social background, likes and dislikes, preferences and predilections, gender and ethnicity, could introduce bias into the research process (see J. L. Johnson et al., 2020; Ravitch & Carl, 2016; Shenton, 2004).

Therefore, during the data collection process, I worked to neutralize bias among participants so that I could control mine. Based on Yin’s (2016) recommendation, I ensured by conducting interviews individually that a particular interviewee’s responses did not influence data from other participants. In compliance with the recommendation of Orange (2016), and Ortlipp (2008), I kept a log of tasks and a reflective journal as part of the interviewing process. In the journal, I reflected about my impressions of each interview and the questions I might need to ask in subsequent interviews. I noted in the reflective journal that as a novice researcher my prompts were not always phrased as open-ended questions. However, participants’ responses were generally detailed and lead to the emergence of unanticipated viewpoints and ideas. I wrote memos that helped me to dismiss my judgments and assumptions (see Shenton, 2004; Thomas, 2013).

During data analysis, I reflected deeply about the influence of my worldviews and assumptions on my interpretations of the interview data. Constantly referencing the TPACK framework, the conceptual framework selected for this study, also guided me in identifying assumptions and propositions that I might have brought to this study and kept me focused on the RQs and the current study's purpose. I made sure that the current study's findings arose from the participants' experiences and ideas, rather than from my opinions and perspectives (see Shenton, 2004; Yin, 2016).

Data Analysis

Data for this current qualitative study on local teachers' integration of ICT into their public high school biology classrooms were analyzed during and after the data collection process. J. L. Johnson et al., (2020) advised that data collection and data analysis run concurrently in qualitative studies as this would help determine what data still needed to be collected. Similarly, Yin (2016) emphasized informal data analysis during the data collection process, when the qualitative researcher is assessing the adequacy of the data and determining if more is needed. Yin outlined five phases for qualitative data analysis (a) compiling the database, (b) disassembling the data into smaller chunks and beginning to assign codes, (c) reassembling and arraying the data, (d) interpreting the data, and (c) concluding.

I employed all five phases in the data analysis process for the current study. As I compiled the interview data, I manually disassembled and reassembled the data, using an Excel spreadsheet to facilitate this. To aid the accuracy of the data analysis process, I also used Dedoose, a QDM software program, to help me compile, disassemble, and reorganize the data so that I could identify emerging codes and themes. Using Dedoose also facilitated the process of identifying coding errors and discrepant cases, thus ensuring that analysis of my study's data was based on inclusiveness rather than anecdotalism (see J. L. Johnson et al., 2020). However, Yin (2016) cautioned about the challenges of using QDM software for qualitative data analysis, a concern being that of the software's ability to analyze textual data. Analysis is dependent on the volume and accuracy of the textual data inputted and the instructions given for sorting, coding, combining, and recombining the text (Yin, 2016). J. L. Johnson et al. (2020) and Yin emphasized that final data analysis still resided in the qualitative researcher instead of the software. Therefore, I was careful to ensure that interview transcripts were accurately transcribed, imported verbatim into Dedoose, and codes were precisely defined within the software. The precise code definitions helped with decisions about when to include or exclude codes. I now present a detailed discussion of how I prepared the data for analysis and analyzed them.

Preparation for Data Analysis

To prepare the data for analysis, I manually transcribed each interview within a few days of the audio recording. I was not discouraged by the tedium of the manual transcription process because it allowed me to reflect on the conversations as I typed. Manual transcription of the audio-recorded interviews forced me to listen to each conversation several times. Thus, I became very familiar with the participants' statements. I listened closely to what each participant said, and I also listened to the nuances of the conversations, the um's and ah's, the pauses, the participants' excited or unexcited comments, the chuckles, and laughter (see Rubin & Rubin, 2012). To ensure accurate transcription, I listened to small chunks of the conversation, then stopped the recording and typed what I heard. I repeated this process to the end of the audio recording. I then listened to the recording again while reading the transcript. I made additions where I had missed words and made changes where I had misheard the participant. The audio recordings were not always clear. There were sometimes drops in the conversation, interruptions, and lost internet connectivity. I sometimes had to ask interviewees to repeat what they said, and vice versa. I read the completed transcript again while listening to the recording to ensure I had captured as accurately as possible what each participant said.

Based on recommendations from Burkholder et al. (2016), Rubin and Rubin (2012), Shenton (2004), and Yin (2016), I made brief field notes during the interviews. Immediately after each conversation, I reflected on the interviewer–interviewee interactions and the information shared by the interviewee. I reflected on the questions that would require particular emphasis in the remaining interviews to address the RQs unequivocally. I added these reflections to my researcher journal. In the researcher journal, I reflected about my propositions, choices, experiences, and actions during the research process as I focused on thematic inductions and conclusions (see Miles et al., 2020; Orange, 2016; Ortlipp, 2008; Saldaña, 2016).

Analysis of Interview Data

In this section I present a clear “paper trail” leading to the discovery of themes, findings, and conclusions related to the current study. Table 3 displays demographic information about the study's participants. The demographic information was obtained during the short preamble before I began the actual interview questions. In the preamble, I asked participants to share information about their teaching career and a little of how the COVID-19 pandemic had impacted them.

Table 3

Participant Demographics: Teaching Experience and Gender

Participant	School pseudonym	Gender	Teaching experience in years
P1	School A	F	8
P2	School B	F	3
P3	School B	M	36
P4	School B	F	6
P5	School B	F	5
P6	School C	F	5
P7	School D	F	13
P8	School E	F	3

Participants are listed in the table in the order in which the virtual interviews were conducted. The participants' teaching experience ranged from 3-36 years. As indicated in the table, P2, P3, P4 and P5 taught in the same Bahamian public high school. P6 could have constituted a discrepant case for the current study, by virtue of her teaching experience. Although P6 has been teaching for 5 years, only the year during the COVID-19 pandemic was in the biology content area. Moreover, P6 had only taught biology in a virtual teaching environment during the 2 weeks immediately preceding our interview. This participant could have presented disconfirming evidence that could have negated some of the data from other participants. Instead, P6's responses gave valuable insights about ICT integration into the biology curriculum from a teacher who had only recently initiated teaching in the biology content area or in a virtual context.

I conducted two practice interviews with persons who would not be in my study but were familiar with using ICT in an educational setting. I coded the two interviews manually and with Dedoose to familiarize myself with the coding process. I identified tentative a priori codes that appeared in the two practice interviews.

After conducting the first few interviews with actual participants I began the first cycle of manual coding. I began to assign codes and identify emerging themes (see Miles et al. 2020; Ravitch & Carl, 2016; Saldaña, 2016; Yin, 2016). I found that some of the a priori codes I had identified from the practice interviews were reflected in the participant data. However, as I examined the interview data to see how they addressed the RQ's, several new codes appeared. Also, as I reflected on the interview data in light of the current study's literature review and conceptual framework, more codes appeared. Codes included ICT tools, Zoom, Google Classroom, convenience, easy to use, sharing content, facilitating assessment, engaging students, challenges, inconsistent internet, electricity issues, large classes, improve teaching, and teachers' technological skills. Table 4 illustrates how some of these codes arose from the current study's literature review.

Table 4

Examples of a Priori Codes Aligned With Literature Review

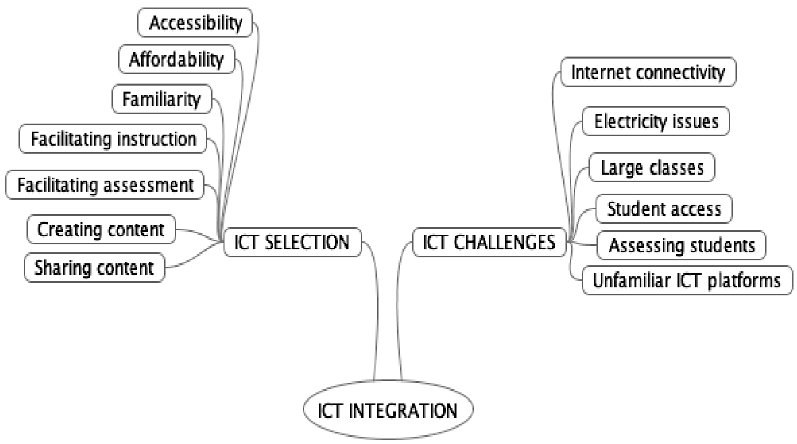
A priori code	Literature reference
ICT tools	Virtual labs provide immersive experiences in real or simulated environments (Hite et al., 2019; Hutchison, 2018)
Teachers technological skills	The extent of teachers' adoption and integration into curricula is varied (Magana, 2017; Maharaj-Sharma et al., 2017)
Internet connectivity	Infrastructural challenges can make ICT integration difficult (Effendi-Hasibuan et al., 2019; Ergado, 2019)
Sharing content	VR/AR in science classrooms allows multimodal information-sharing in the form of written text, images, video, and audio (Hutchison, 2018; Sahin & Yilmaz, 2020).
Improved learning	Educational technology interventions showed only modest improvements on student achievements (Makransky et al., 2019; Al Ghazali, 2020)
Teachers' needs for improving ICT use	PD workshops on ICT integration in classrooms can enhance teachers' TPACK and influence them to transform their teaching (Alemdag et al., 2020; Mishra et al., 2019)

As I examined the interview transcripts for codes and built my first code tree, I kept in mind the current study's purpose which was to explore biology teachers' integration of ICT into their classrooms. I began to group the codes into categories based on the RQs. For example, I selected a category labeled ICT selection related to RQ1, and included codes such as ICT tools, accessibility, affordability, familiarity, facilitating instruction, facilitating assessment, creating content, and sharing content. As another example, I chose another category labeled challenges for ICT integration that was related to RQ2. Under this category, I placed codes such as internet connectivity, electricity issues, unfamiliar ICT platforms, large classes, student access, and assessing students.

I also considered the current study's conceptual framework in the development of a priori codes. Therefore, the codes reflected elements of TPACK. For example, ICT tools and familiarity were related to teachers' TK, and facilitating instruction and assessment reflected teachers' PK. Figure 2 illustrates how I built my first code tree for the categories of ICT selection and challenges for ICT integration.

Figure 2

Qualitative Code Tree for ICT Integration



I created a Microsoft Word codebook. I also inputted the categories, codes, and their descriptions into Dedoose as my digital codebook. I then uploaded the interview transcripts into Dedoose and began to code them using both codebooks. I added additional codes as they emerged from the transcripts. I completed the first level of coding with all interviews. I copied and saved the interview transcripts and pertinent annotated codes from Dedoose on my password-protected computer.

In my second coding cycle, I began to revise and refine my Microsoft Word codebook. I labelled the categories I used for grouping codes as emergent themes. I aligned the codes to the RQs to ensure that the data addressed the RQs. I merged or collapsed codes where there appeared to be redundancy, deleted or added codes, rearranged the categorization of some codes, and re-defined some of them. For example, I merged the codes of accessibility and affordability as a logistical theme under ICT selection, and combined internet connectivity challenges and electricity issues to create the infrastructural/technical theme under ICT challenges. I precisely defined the attributes of each code to be able to decide its inclusion in, or exclusion from a particular theme. At the end of this revamping exercise, the Microsoft codebook contained a manageable and clearly defined list of codes I could apply to unearthing ontological and epistemological knowledge from the data collected. Table 5 shows the alignment between RQ's, initial codes, merged codes, and emerging themes in the revised codebook.

Table 5

Alignment Between RQs, Codes, and Emergent Themes

RQ	Initial code example	Merged code	Emerging theme
RQ1: How do local public high school teachers decide to use ICT in their classrooms to deliver the biology curriculum?	Google Classroom, PPT, Microsoft Teams, etc.	Specific ICT tools	ICT selection
	Accessibility/Availability; affordability; convenience/time-saving/ease of use	Logistical	
	Familiarity; facilitating instruction; facilitating assessment	Teachers' TK and PK	
RQ2: What challenges do local public high school biology teachers experience in their integration of ICT into their biology classrooms?	Internet challenges; electricity issues	Infrastructural/ technical	Challenges of ICT integration
	Completing the curriculum; assessing students	Pedagogical	
	Train students in ICT use; use their personal internet and devices	Mitigating challenges	
RQ3: What additional support, knowledge, or skills do teachers need to improve ICT use in their classrooms to positively impact student achievement in biology?	Transformed pedagogy; improved TK and PK	Values added	Teachers' viewpoints on ICT integration
	In-school ICT training; government–teacher unified technology policy/plan	Improving ICT use	

I then embarked on a new coding exercise in Dedoose. First, I entered the emerging themes as root codes. After regrouping and merging initial codes as firm structural codes developed from the study's data, I entered them as child codes, and their definitions in the code description section of the software. I then commenced a data-driven open-coding process where I conducted deep content analysis of the data. Using Dedoose expedited the coding process and relieved the tedium of manual coding. With Dedoose I was able to perform quick axial coding where I "linked" or connected relevant data segments within and across interview transcripts, forming clusters or networks of information (see Miles et al., 2020). Targeting evidence to support my inductions was also easier with Dedoose.

Analysis of the interview transcripts was not a linear process, as noted by Saldaña (2016) because information relating to the designated codes and emergent themes resided at the top, middle, or bottom of the transcripts. Although not conducting a quantitative study, I used Dedoose to track how often particular codes and themes appeared among the interview transcripts. I used these occurrences to help to decide the importance of codes. Also, the number of times that codes appeared helped to determine data saturation (see Francis et al., 2010).

I examined each interview transcript closely, searching for commonalities and differences among them (see Miles et al., 2020; Saldaña, 2016; and Yin, 2016). The similarities and differences provided essential data points to be considered in inducing findings. Table 6 is an excerpt from a Microsoft Word document I created to show congruence between transcripts. In the table I have only included transcripts from P3, P5, and P8. Checkmarks indicated that the code appeared in the particular transcript. Empty boxes indicated that the code was not found. As indicated in the table, there were many similarities in the ICT integration experiences reported by teachers in the current study.

Table 6

Code Congruence in a Sample of Interview Transcripts

Theme	Code	Participant		
		P3	P5	P8
ICT selection	Google Classroom, PPT, Microsoft Teams, etc.	√	√	√
	Convenience/time-saving/ease of use	√	√	√
	Availability/accessibility	√	√	√
	Familiarity	√	√	√
	Facilitates instruction	√	√	√
Challenges	Infrastructural/technical	√	√	√
	Completing the curriculum	√	√	√
	Assessing students	√	√	
Improving ICT integration	Transformation of learning achieved		√	
	Relevant PD/training needed	√	√	√
	Revised government technology policy/plan needed	√	√	√

In my revised and refined codebooks, I carefully recorded quotes from interviewees in support of the codes and themes. At the end of the coding process, and after coding all transcripts, I downloaded the coded transcripts from Dedoose and uploaded them and my Microsoft Word qualitative codebook to my chair and methodologist for their approval and permission to continue writing Section 2.

Evidence of Quality

I employed several procedures to establish the validity of the current study. To ensure credibility, I followed recommendations from Ravitch and Carl (2016), Shenton (2004), and Yin (2016) to adopt well-established research methods and tools for data collection and data analysis. I was careful to not only collect thick, rich, data from participants but also to safeguard the data on my password-protected computer and in the cloud. I listened carefully to the participants and avoided introducing personal bias by not interjecting my opinions into the conversations. I carefully and repeatedly checked each manual interview transcript against its' audio-recording to ensure accuracy.

I ensured dependability of the study's data, by employing participant validation and member checking of the transcripts (see DeCino & Waalkes, 2019; Ravitch & Carl, 2016; Yin, 2016). At the end of the data analysis process, I wrote a summary of my interpretation of each interview. I emailed each synopsis to the relevant participant and requested a review for accuracy and clarification of any section that reflected an inaccuracy. I received responses from five participants. Four of the respondents stated that my interpretations of their interviews were accurate. P1 made a single correction to the summary. She said that she had not used an ICT tool I had attributed to her. P5 confirmed the accuracy of her interview but used the opportunity to add to the responses given during the virtual interview. I uploaded the additional information into Dedoose and re-analyzed the data to include the new information.

To ensure confirmability, I focused intently on how the data addressed the current study's RQs (see Peterson, 2019). I counter-checked the manual data coding against Dedoose's coding software to confirm the validity of codes as they emerged (see Ravitch & Carl, 2016) and I allowed my codebooks to evolve with data added sequentially from the interviews. I searched for multiple examples from the data to support my inductions, but I also scrutinized transcripts for disconfirming or discrepant data (see J. L. Johnson et al., 2020). Discrepant data were essential to validating my conclusions. I established a clear "paper trail" from data analysis to the development of the study's findings by keeping a log and reflective journal. In the reflective journal I tracked my analysis of each interview, and noted adjustments I would need for subsequent interviews. Allowing the study's outcomes to emerge solely from the data prevented projecting my personal experiences, values, expectations, and perspectives into the data (see Miles et al., 2020; Orange, 2016; Ortlipp, 2008; Saldaña, 2016). To further ensure validity, I examined similar studies and related the current study's conclusions to the previous research (see Ravitch & Carl, 2016; Shenton, 2004; Yin, 2016).

Procedures for Dealing With Discrepant Data

Discrepant data are the disconfirming, negative cases, or outliers that seem to deviate from what the researcher considers the norm (Ravitch & Carl, 2016). Data that seem to deviate from other responses increase validity by presenting evidence that challenges and complicates a study's findings (Ravitch & Carl, 2016). I analyzed data for the current qualitative research on local teachers' ICT integration into their public high school biology classrooms at the group level to de-identify participants. However, I remained alert for individual discrepancies. Rubin and Rubin (2012) suggested that alternative viewpoints are crucial in the thematic induction process. Keeping and reviewing analytic memos, being alert to negative instances, developing rival explanations, and posing questions about the data, were techniques I used to identify discrepant data (see Rubin & Rubin, 2012; Thomas, 2013; Yin, 2016). I did not dismiss or trivialize discrepant data, instead I incorporated this data into the development of valid inductions for the study, as recommended by Rubin and Rubin, Thomas, and Yin. The attention paid to discrepant data was important in decreasing subjectivism in the study's findings, as proffered by Thomas and Yin.

Limitations

The collection of copious, descriptive data is characteristic of qualitative research (Ravitch & Carl, 2016; Yin, 2016). However, a qualitative approach delineates certain limitations, such as this current study's small number of participants and study sites. The narrow representation of this current research might not allow theoretical saturation, nor replication of the research process (see Carminati, 2018). Also the qualitative approach may not lead to generalization of the current study's findings (see Carminati, 2018; Ravitch & Carl (2016); Yin, 2016). However, Carminati (2018), and Peterson (2019) proffered that qualitative studies have a more important objective of transferability to other situations over generalizability to all situations.

The current study's data derived solely from virtual interviews, where participants shared self-reported information, personal recollections, and opinions. As noted by Yin (2016), interview data could provide an incomplete picture of phenomena under investigation, and participants can misconstrue field questions. Participants in the current study might not have recalled, or reported significant events, and their reporting of their ICT integration experiences might be inaccurate. Also, because of previous collegial relationships some participants might have assumed that I had prior insights about the problem being explored and might not have elaborated deeply on their experiences with integrating ICT into their biology classrooms (see Rubin & Rubin, 2012; Thomas, 2013). Conversely, as noted by Ravitch and Carl (2016), and Rubin and Rubin, unfamiliarity between other participants and myself might have affected the close interviewer–interviewee rapport needed to generate the thick, rich data needed for the current study. Although I conducted one-on-one interviews to gain independent reports of the phenomenon under exploration (see Yin, 2016), participants in the current study could have discussed their responses with other persons connected or not connected with the research.

The time period for data collection could be a significant limitation for research studies (see Ravitch, 2020). Data for the current study were collected during the COVID-19 pandemic, an occurrence that might have influenced participants' behaviors and responses (see Ravitch, 2020). The shared trauma of the COVID-19 might have affected the participants' valuation of the research and their memory of events related to the current study (see Ravitch, 2020). Lambert (2012), and Thomas (2013) noted the existence of the 'Hawthorne Effect' where participants' responses could be affected by the researchers' interest in their experiences. This study's participants could have exaggerated their reports of ICT use because of my interest in their ICT experiences in their local biology classrooms.

Data Analysis Results

In this section I briefly review my data collection procedures and present a detailed analysis of the data and the development of themes and findings. After obtaining approval from Walden University's IRB, I conducted participant recruitment between April 30, 2021–May 31, 2021. I obtained eight participants. I collected data using virtual interviews facilitated by Zoom from the eight biology teachers between May 11, 2021–June 7, 2021. I manually transcribed all eight interviews and coded the transcripts manually and with the aid of Dedoose qualitative data management software.

The current study incorporated three RQs. RQ1 was “How do local public high school teachers decide to use ICT in their classrooms to deliver the biology curriculum?” RQ2 was “What challenges do local public high school biology teachers experience in their integration of ICT into their biology classrooms?” RQ3 was “What additional support, knowledge, or skills do teachers need to improve ICT use in their classrooms to positively impact student achievement in biology?” In developing the interview protocol that generated data for the current study, I designed interview questions (IQs) to address the RQs (as shown in Table 2).

Development of Themes and Key Findings

Coding of the interview transcripts led to the development of themes and key findings. I aligned the codes with the RQs to ensure that the data addressed the research questions. In this section I discuss the development of themes for each RQ, followed by a discussion of the key findings related to the RQs.

Three themes related to RQ1 emerged. These were ICT selection, logistical, and teachers’ technological knowledge (TK) and pedagogical knowledge (PK). Three themes related to RQ2 also emerged. These were infrastructural/technical challenges, pedagogical challenges, and mitigating challenges. The themes of values added and teachers’ viewpoints on improving ICT use emerged from aligning codes with RQ3. Table 7 shows the emergent themes for each RQ.

Table 7

Alignment of Research Questions to Themes

Research question	Emergent theme
RQ1: How do local public high school teachers decide to use ICT in their classrooms to deliver the biology curriculum?	ICT selection Logistical Teachers' TK and PK
RQ2: What challenges do local public high school biology teachers experience in their integration of ICT into their biology classrooms?	Infrastructural/technical Pedagogical Mitigating challenges
RQ3: What additional support, knowledge, or skills do teachers need to improve ICT use in their classrooms to positively impact student achievement in biology?	Values added Viewpoints on improving ICT use

In the following sections I discuss emergent themes for each RQ. I refer to the data to validate my thematic inductions. I quote teachers' actual statements or paraphrase their statements from the interview transcripts.

Research Question 1 Themes

The themes related to RQ1 were ICT selection, logistical, and teachers' TK and PK. Codes for ICT selection included Google Classroom, Microsoft Teams, and virtual labs. Codes identifying the logistical theme included availability and ease of use. Codes identifying the TK and PK theme included familiarity, engaging students, and transforming pedagogy. Table 8 shows the codes and occurrences that led to the emergence of themes.

Table 8

Codes and Code Occurrences for RQ1 Themes

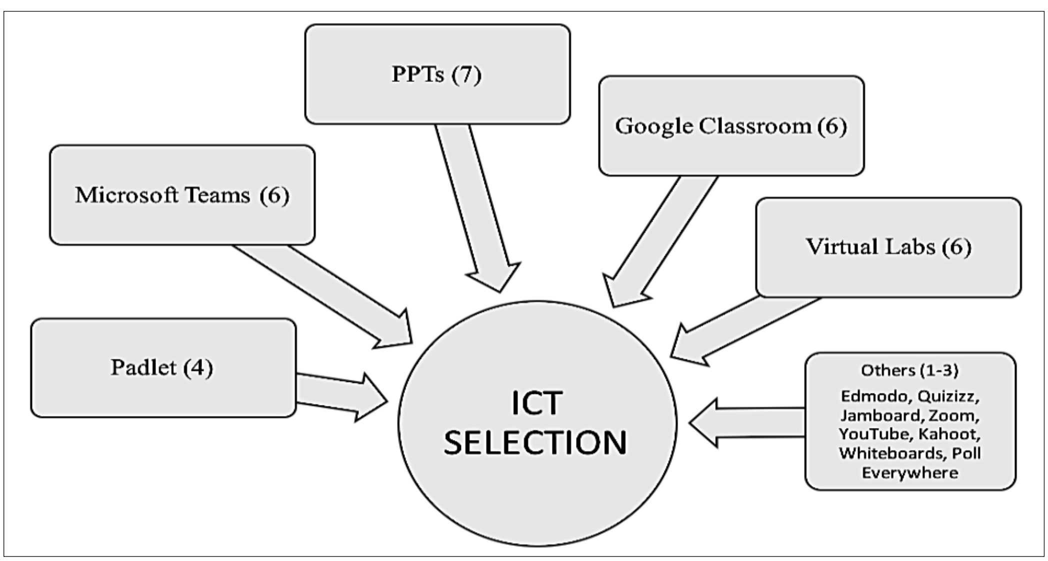
RQ1 Theme	Code	Occurrence in transcripts
ICT selection	PPTs, Google Classroom, Microsoft Teams, Virtual Labs, etc.	>240
Logistical	Availability/accessibility; affordability; convenience/time-saving/ease of use	19
Teachers' TK and PK	Familiarity; facilitating instruction; facilitating assessment; engaging students; transforming pedagogy	69

ICT Selection

The first theme relating to RQ1 was ICT selection. The current study's eight participants itemized the specific ICT tools they used before or during their virtual and blended teaching. Figure 3 shows the variety of ICT tools selected by the biology teachers, along with the number of teachers who used the particular tools.

Figure 3

Specific ICT Tools Selected



The most often-used ICT tool was PPTs. Seven of the eight biology teachers reported that they used this ICT tool in their virtual or blended classrooms. Following closely behind PPTs were Google Classroom, Microsoft Office Teams, and virtual labs, where six of the eight biology teachers stated that they used these ICT tools. Only one to three teachers used other ICT tools such as Edmodo, Quizizz, Zoom, and Whiteboards. Participants cited specific ICT tools more than 240 times during the virtual conversations.

Analysis of the interview data revealed that the decision to select ICT tools to facilitate virtual and blended teaching was not solely in the hands of the biology teachers. Instead, ICT tool selection was shown to be a multi-pronged decision involving the MOEST, schools, biology teachers working independently of other biology teachers, and biology teachers collaborating with other biology teachers in a school. Participants P3, P4 and P8 noted that before initiating virtual education, the MOEST launched a virtual LMS with Microsoft Teams as the ICT tool for facilitating online classes. P3, P6 and P8 noted that their schools' administrators offered workshops before starting the virtual teaching launch to familiarize teachers with apps and tools that could facilitate virtual teaching, engage students, and motivate learning. P8 used Microsoft Teams on the MOEST's LMS and also used other ICT tools such as Quizizz and Kahoot that she selected on her own. Working on her own, P6 opted to use Google Classroom and YouTube.

The biology teachers from School B collaborated on ICT tool selection and decided to accept and use the MOEST's recommendation of Microsoft Teams, along with other ICT tools such as Google Classroom and Padlets that they selected together. P3 from School B, stated "I did some reading, and my colleagues with me, asked them what they used, and we tried different ones based on our experiences." P5, also from School B said "we're just constantly trying different things," and "we make decisions as one."

Logistical

The second theme aligned to RQ1 was logistical, and included three codes of availability/accessibility, convenience/time-saving/ease of use, and affordability of the ICT tools. Seven of the eight participants cited logistical reasons for ICT tool selection. The first code under this theme was accessibility/availability of ICT tools. P4 stated that she selected ICT tools that allowed students to log on from the same email address they already had for the Google Classroom. Other biology teachers reiterated the necessity for the ICT tool to be available to teachers and students, and for students to be able to access the tool. P3 stated that he chose to use Google Classroom where he could give the students an email address to access the class and all of their work would be in one place.

The next code under the theme of ICT selection was affordability. Participants stated that ICT tools needed to be inexpensive so teachers could afford to access them and use them. In most instances the teachers used free versions. P1 stated "I know that Zoom allowed you to have free meetings for 40 minutes, so that was helpful." P6 shared "cost is one of the biggest factors since we don't have the budget for it. Most of the things online are free, so I use those instead." P6 also said that even if the ICT was not free, most of those she used were not so expensive as to preclude her using it.

The last code that represented logistical reasons biology teachers decided to use ICT was that the tools were convenient, time-saving, and easy to use. As stated by P4 "there were so many things to get done in such a short timeframe, deadlines and all those things coming up. We wanted to use apps that were quick and easy." P2 also shared that the ICT tools selected by biology teachers at School B were the simplest versions for students to use in virtual classrooms during the COVID-19 pandemic.

Technological and Pedagogical Knowledge

The third theme aligned to RQ1 was teachers' TK and PK in their decisions to use ICT tools in their remote classrooms. This theme included the codes of familiarity with ICT tools, facilitating instruction, facilitating assessment, and engaging students. Data analysis revealed teachers' TK and PK as the most important consideration in the decision to select ICT tools. Teachers' TK and PK as reasons for ICT selection were tagged 69 times whereas logistical was tagged only 19. Several participants revealed their TK by sharing that they were already familiar with ICT tools. For example, P8 said "I normally already use a lot of PPTs and a lot of visuals. I am a very hands-on teacher." P7 shared that the ICT selection was based on her level of training with the ICT tools.

However, participants possessed varying levels of TK. For example, P3 shared that he had extensive technical knowledge related to virtual teaching, and stated "I've always done some online teaching." P3 further noted that his school's administrators recognized his technical competence and he was asked to serve as a facilitator in the technology seminars implemented in his school to prepare teachers for virtual teaching. P5 shared discrepant data by stating "I did not know what Google Classroom was prior to last March. So, I learned that. I'm learning how to use some of these apps." Similarly, P6 shared "I didn't even know some of the platforms existed, and after doing the courses now I know that I can actually do this thing." Teachers who had little TK prior to virtual teaching appeared willing to learn the new technologies needed to access, instruct, and assess students within their virtual and blended classes. Improving their TK by collaborating with their peers was an avenue resorted to by some teachers. For example, in referring to her colleagues' superior technological knowledge, P5 stated "I'll say give me a quick rundown, because I don't have time to go and read and watch millions of YouTube videos, so explain it to me."

The codes of facilitating instruction, facilitating assessment, engaging students, and transforming pedagogy reflected teachers' PK. P7 said "I diversified my assessments with different platforms, and engaged students with, yeah, different platforms for assessment and for reinforcement of content." P5 stated "We also kept integrating various ICT tools, not just based on familiarity etc., but also to finding different ways to keep students' interest." P4 shared that teachers at her school transformed their pedagogy by using ICT tools such as Google Classroom to post notes, videos, and updates for students, and Microsoft Teams to share content with students. Based on the interview data, biology teachers' pedagogical knowledge was more important than technological knowledge in the decisions to integrate ICT into local biology classrooms. Of the 69 times that teachers' TK and PK were cited as a reason for ICT selection PK was mentioned 43 times, whereas TK was mentioned 26 times.

Based on the themes and codes for RQ1, the key finding was that local biology teachers decided to use ICT based on logistical issues such as affordability and convenience, their TK such as familiarity with ICT tools, and their PK such as how well ICT helped them teach and assess students' learning.

Research Question 2 Themes

RQ2 was "What challenges do local public high school biology teachers experience in their integration of ICT into their biology classrooms?" Two themes of infrastructural/technical challenges and pedagogical challenges emerged from data analysis. A third theme was teachers' mitigation of the challenges. Table 9 summarizes the codes and code occurrences that led to the emergence of themes.

Table 9

Codes and Code Occurrences for RQ2 Themes

Theme	Code	Occurrence in transcripts
Infrastructural/technical challenges	Internet issues; electricity issues; accessing students	37
Pedagogical challenges	Completing the curriculum; assessing students; teaching hands-on skills	35
Mitigating challenges	Used their own devices and personal internet; gave paper worksheets; trained students in ICT use; team-teaching	42

Infrastructural/Technical Challenges

Codes that identified the infrastructural/technical challenges theme included electricity issues, internet issues, and accessing students. P2, P3, P4 and P5 reported the challenge of intermittent electricity. However, P4 stated that internet connectivity was the main infrastructural/technical challenge. She stated "It was constantly dropping at school." P2, P3 and P5 also noted difficulties with internet connectivity in their school, but this was not an issue reported in all schools. P7, from School D presented discrepant data when she stated "in terms of internet, we do have good internet service. So, using technology is easy. It's easy for students to use." The consistency of the internet service and electricity supply at School D were attributable to the fact that the school supplies its own electricity through solar panels, an affordance not available to any of the other schools. However, the consistency of the internet service at P7's school did not negate the existence of internet connectivity challenges reported by other participants.

P4 and P7 shared another issue of many students not having access to digital devices and therefore being unreachable in virtual classrooms. P5 alluded to socio-economic factors preventing some students from obtaining suitable devices or accessing virtual classes. P5 stated "Sometimes the ministry has given them the devices, but still we have students who couldn't do the work for months or two because they didn't have any internet connection where they live, cable, light, whatever, I don't know." P3 remarked "because we're using the free versions, it does not allow to reach all the students."

Pedagogical Challenges

Codes that identified the pedagogical challenges theme included completing the curriculum, assessing students, and teaching hands-on science skills. P2 stated "some of the coursework-related assignments, like some experiments, they aren't able to do virtually." P1, P3, P4, P5 and P8 also reported the challenge of teaching practical hands-on scientific skills and assessing students' grasp of those skills on a virtual platform. P8 commented "if we had labs where we actually virtually do these things they would have understood it so much more." P8 opined that on a virtual platform it would have been helpful for students' engagement to have some actual hands-on science activities.

At School B, teachers faced an additional pedagogical challenge related to teaching large classes. P3, from School B, shared "but, my big challenge is the huge, large class size. Because of those large class size I don't think I was really reaching the students the way I like." P3 explained that teachers in School B normally taught classes of 30-35 students in FTF classrooms, but were now teaching classes of 100-200 students in virtual classrooms. P3 posited that the large classes resulted from the MOEST's effort to accommodate as many students as possible in the LMS.

Teachers also noted challenges with students' attendance to virtual classes and students' lack of expertise in using technology for learning. P3 stated "but over the weeks we've seen a fall-off in students coming online." P2 posited that students' non-attendance or 'ghosting' affected their completion of assignments. She stated "because they're at home, students thought that, may have felt that they're on vacation." Teachers also surmised that students experienced time management challenges in coping with their virtual timetables and managing their daily social media activities in conjunction with attending virtual classes (P2; P4). Additionally, P3 and P5 opined that students lack of technological expertise affected the instructional pace in virtual classrooms. P3 stated "We've had to have the students enrolled, teach them what email to use, how to do the assignments." P5 noted that the time constraints of teaching technological skills to students before beginning to share content with them reduced instructional time.

Mitigating Challenges

Teachers' mitigation of challenges included the codes of used their own devices and personal internet, gave paper worksheets, trained students in ICT use, and team-teaching. Unquestionably, frustrations arose in the face of many challenges with integrating ICT into the biology curriculum in the new virtual learning environment. P4 stated “some things worked, but there were a lot of things that needed to be corrected or changed a little bit to incorporate the new dynamics.” P5 noted “The Ministry had their thing but it wasn’t as up and running as we would have wanted it. So, we had to find an alternative means.”

Mitigating challenges was tagged more than 40 times in the coding process. All of the current study’s participants noted that they were given a tablet from the MOEST, but that the tablet was ineffective for virtual teaching. All participants shared that they used their own devices in place of the devices provided to them by the MOEST. As P6 succinctly stated “I have my own tablet that’s more advanced. I have my own laptop that’s advanced. So, I use my own stuff.”

Teachers in the current study noted that in dealing with inconsistent internet connectivity, they also used their personal internet. P1 shared “So, with the PPT and the videos, I’d have to have those downloaded before I go to school because my lab didn’t have internet.” For students who did not have access to devices for virtual learning, or had no internet at home, or for any other reasons were unable to join virtual classes, P2 shared her school’s method of addressing the challenge:

> So, what the school did was that they created a book of notes and activities that those students would have to come to school and complete. As well as with the hybrid, what happened was that they came to school couple days and they worked at home couple days. So, those students that were not able to come to the online class, when they were in school they can get the same assignments and missing work and do it there.

P1 noted that it was difficult to assess students' grasp of hands-on scientific skills on virtual platforms. To mitigate the challenge some teachers accepted the MOEST's allowance to replace this syllabus component with an alternative examination component labeled Paper 5. P8 explained that the Paper 5 component was to "walk students through how a lab should look." However, P8 also commented "The students felt like it was just another paper to write, instead of feeling like it was a way to interact and do things in Science." Some teachers used virtual labs to teach the practical hands-on component of the biology syllabus, but commented that virtual labs were sometimes cost-prohibitive or did not offer suitable experiments for the Bahamian context. Neither the Paper 5 option nor the virtual lab option appeared a perfect solution for the challenge.

To mitigate against the remote nature of virtual classrooms, teachers in the current study built cognitive presence by developing new learning activities geared for students. For example, P5 shared "our PPTs, they won't be just a 20-minute talk. They have to be interactive for the entire time you're there." Teachers worked hard to create authentic connections with their students, frequently calling students on the virtual platforms, and giving flexible times when students could contact them virtually. To ensure student engagement in the new virtual learning arena, teachers trained students to use the ICTs and taught them proper netiquette. As P5 stated "I found that while we say this generation is tech-savvy, they were not tech-savvy in using it for school," and "every time you learn something new you have to go and teach it to the students." To mitigate the challenge of teaching large classes, teachers at School B noted that they employed team-teaching techniques to help with managing the large virtual classes.

The teachers' mitigation of challenges with the new remote education initiative was succinctly summarized by P5 who stated "Constant trial and error helped us understand what enhanced the lessons and student learning." P5 spoke about the amount of planning required for online teaching and the uncertainty about the effectiveness of the initiative. P5 stated "So, it's a lot of planning and executing, and sometimes things work, sometimes it doesn't work. So, you have to put tweaking in and see what works for one class may not work for the next class."

Research Question 3 Themes

RQ3 was "What additional support, knowledge, or skills do teachers need to improve ICT use in their classrooms to positively impact student achievement in biology?" The themes of values added from ICT use and teachers' viewpoints on improving ICT use emerged from the data. The themes aligned with RQ3.

Values Added

For the theme of values added, I identified three codes of improved TK and PK, transformation of learning, and improved teacher collaboration. Despite the challenges reported by local biology teachers in integrating ICT into their virtual and blended classrooms, participants shared examples where the ICT integration augmented their TK and PK. Most responses related to improved TK. For example, P3, who shared that he had excellent technological skills before starting virtual teaching at his school, said "since the pandemic start, I became more aware of other interactive tools that I can use to enhance my teaching." P6 stated "even though I don't have the resources to dissect a frog, we could do this online and then they still feel a part of doing some real science." Only a few instances of improved PK were mentioned. P8 shared,

> It helped me to understand that I have to do self-reflection, and not every lesson is a one size fit all. Some of them I will have to adapt. Something that worked in person may not work virtually, and something that worked virtually may not work when they come face-to-face.

Five participants shared about valuable teacher-teacher collaborations that developed from teaching online. Interview transcripts from the teachers in School B confirmed that biology teachers from this school selected ICT tools together, created content and assessments together, and applied team-teaching techniques to manage large class sizes. In speaking about the teacher-teacher collaboration, P3 from School B shared "I'm able to see their strength, and how we work together. So that's a plus from this whole integration." P4, also from School B, stated:

> It also helped me as a teacher because we were team-teaching and I could see other teachers' teaching styles, and the things that they would do and how they would teach different topics. That helped me because now I can better deliver to my students by using some of those techniques that were used as well.

Questions about values added for students presented disconcerting data. Most participants in the current study did not believe that virtual teaching and learning added value for students. Only two teachers proffered that virtual teaching allowed more content to be delivered to students (P2), and improved communication with students (P5). P1 posited that there was no improvement in student learning from the virtual classes.

The remaining teachers were undecided about improvement to student learning afforded by ICT integration into virtual classrooms. P7 opined that students initially gained from the virtual experience but overall did not benefit. P5 noted that as with FTF classes, students in virtual biology classrooms still struggled with learning content. However, P3 posited that although a high percentage of students did not benefit from the virtual experience "the students were able to get the best of each teacher based on the content, and that is something we should not give up." P8 noted that her students did not like alternating between virtual and FTF classes and were anxious to return to in-person classes. The impact of virtual teaching on student learning, though not the focus of this study, appears to warrant future research. Table 10 shows the teachers' responses related to the codes of improved teachers' TK and improved student learning.

Table 10

Teachers' Responses to Values Added Codes

	Teacher response		
Code	Improved	Not improved	Uncertain
Teachers' TK	7	0	1
Student learning	2	1	5

Viewpoints on Improving Information and Communications Technology Use

For the theme of viewpoints on improving ICT integration, I identified four codes of in-school ICT training and support, relevant ICT PD/training, community or other partnerships, and unified government–teacher technology policy/plan. P1 and P5 shared that support from school administrators and other teachers helped in transitioning to virtual teaching. According to the teachers, their schools provided technological training and ICT recommendations for teaching virtual classes (P3, P6). Some of the study's participants acknowledged the helpfulness of the training in online teaching afforded by their schools before the launch of virtual instruction. For example, P6 noted that after doing courses provided by her school, she gained expertise in selecting online ICT tools that she used in virtual classes. Teachers at School B mentioned attending workshops at the school and felt that the initiative should continue but made more effective.

All participants voiced the need for PD relevant to the biology subject area. P7 noted "We are teacher-trained, however, we're not technology-trained." P7 stated that the government needs to know what tools biology teachers use, need to use, are interested in using, and provide those tools. P8 stated:

> So, if we can incorporate our professional development for biology solely on ICT integration into our subject, I think that will be a big help for me. Instead of me having to do my own research and figure out ways that I can integrate ICT.

Several times, teachers mentioned a need for additional support involving community and other partnerships. The code was mentioned 8 times. P8 and P6 noted that community and other partnerships could improve ICT use in biology classrooms. P8 suggested allowing teachers the option of contacting community partners to bring more ICT into classrooms. P6 reflected on teacher-teacher partnerships by stating "if everyone is on the same page on getting the students where they need to be, that would go well. Because now I can share my ideas with you, and you can share yours with me."

Participants were particularly vocal about a need for the government to revamp its current technology policy/plan with input from teachers' experiences integrating ICT into their classrooms. P8 stated "A lot of decisions are being made in terms of education behind closed doors, and the teachers, the ones who are forced to carry out these changes are not involved on these conversations." P3 noted that the government needed to get information on ICT integration from the teachers "because it's right there, and I think teachers are willing to express and to share the experiences they have." P8 stated:

> COVID has forced us to go into technology. The ministry needs to acknowledge that times have changed and we've already started that transition and we need to continue that transition into going digital, and to look into ways of incorporating all those technological and ICT programs into our classrooms.

Teachers also suggested a need for government to revamp the biology curriculum to include lessons learned from teachers' classroom experiences integrating ICT. For example, P1 and P8 suggested shortening the syllabus. P1 and P8 opined that the syllabus was already lengthy for the FTF learning environment, much less for the virtual classrooms where teachers saw students less frequently, needed to train students in ICT use before teaching biology content, and were constantly reopening assignments for students. P5 and P8 suggested making the curriculum more relevant to the Bahamian setting. Several teachers in the current study stated a need for developing additional online resources for teaching and assessing the practical hands-on skills component of the Bahamian high school biology syllabus. P8 noted that conversations among colleagues included the possibility of the government changing the format for the national biology examination to a digital one. Although taught on virtual platforms, students still write paper and pen examinations at physical examination centers (Hamilton, 2021).

In analyzing the interview transcripts, I noted how often the codes related to the theme of viewpoints on improving ICT use occurred. The code of creating a unified government–teacher technology policy plan outnumbered the other codes. Table 11 shows the occurrences for each code.

Table 11

Code Occurrences for Viewpoints on Improving ICT Use Theme

Code	Occurrence in transcripts
In-school ICT training and support	21
Relevant ICT PD/training	11
Community or other partnerships	8
Unified government–teacher technology policy/plan	38

Key Findings

In this current qualitative study, I explored local biology teachers' ICT integration into the Bahamian public high school biology curriculum. Based on the study's problem, purpose, and conceptual framework, I created three RQs before collecting and analyzing data to address those questions. After data analysis, I determined four key findings aligned to the RQs, as shown in Table 12.

Table 12

Alignment of Research Questions to Key Findings

Research question	Key finding
RQ1: How do local public high school teachers decide to use ICT in their classrooms to deliver the biology curriculum?	Local biology teachers decide to use ICT based on logistical issues such as affordability and convenience, their technological knowledge such as familiarity with ICT tools, and pedagogical reasons such as how well ICT helps them teach and assess students' learning.
RQ2: What challenges do local public high school biology teachers experience in their integration of ICT into their biology classrooms?	The challenges biology teachers experienced in integrating ICT into their classrooms related to infrastructural/technical issues, such as technology or internet not working, and pedagogical challenges such as not enough time to finish the required curriculum, and difficulty assessing students. Local biology teachers overcame challenges by using their personal internet and devices, training students on technology use, and in some cases employing team-teaching techniques to share expertise.
RQ3: What additional support, knowledge, or skills do teachers need to improve ICT use in their classrooms to positively impact student achievement in biology?	ICT integration added value to local biology classrooms, but teachers wanted to improve the integration through additional in-school training and support, more teacher and community collaborations related to ICT use, and a unified government–teacher technology policy/plan that includes increased ICT provisions and relevant ICT PD/training in the content area.

Here I discuss in detail the four key findings and their connection to the study's problem, purpose, and RQs. I also discuss how the key findings relate to the constructs of Mishra and Koehler's (2006) TPACK, the conceptual framework that grounded the study. I explain how the study's key findings confirmed and extended the existing literature on ICT integration into education.

Key Finding From Research Question 1

RQ1 was "How do local public high school biology teachers decide to use ICT in their classrooms to deliver the biology curriculum?" The key finding related to this RQ was that the teachers in the current study decided to use ICT based on logistical reasons such as affordability and convenience of the ICT tools. The teachers also involved their TK, such as familiarity with the ICT tools, and their PK, such as how ICT can facilitate instruction and assessment of student learning.

Teachers in the current study shared that affordability and convenience of specific ICT tools were important factors in deciding to use ICT in their classrooms. They shared that most of the ICT tools they selected were free and easy for students to use, and cited specific examples such as Zoom, Google Classroom, and Padlets. This finding on how teachers selected specific ICT tools is similar to previous research by Heitink et al. (2017) and Magana (2017). The current study extended this finding for Bahamian biology teachers delivering instruction remotely during the pandemic. Therefore, my study's data confirmed and extended findings from the literature.

The key finding related to RQ1 also related to the conceptual framework underpinning the study. TPACK is a major influence on teachers' ICT integration into their classrooms (M. J. Koehler et al., 2013; Magana, 2017; Ocak & Baran, 2019; Willermark, 2018). The biology teachers in the current study demonstrated their TPACK in their decisions to integrate ICT into their virtual classrooms. Firstly, the teachers demonstrated TK in sharing that they were already familiar with some of the ICT tools they decided to use for their virtual classrooms, as also reported in studies by M. J. Koehler et al., (2013), and Willermark, (2018), thus confirming and extending findings from the literature.

Secondly, teachers in the current study cited PK as the most important factor in the decisions about using ICT tools in virtual and blended classrooms. Researchers such as Naji (2017) and Sargent (2017) highlighted teachers' selection of ICT tools for pedagogical reasons such as boosting student engagement and motivation to learn. Alemu (2017) and Yilmaz (2017) posited that ICT integration could transform pedagogy, for example by allowing flexibility of content and delivery. Teachers in the current study demonstrated PK in their selection of ICT tools such as Google Classroom and Microsoft Teams for engaging students, sharing content, facilitating instruction and assessment, and transforming teaching. Teachers in studies conducted by Yilmaz (2017) and Alemu (2017) selected similar ICT tools for similar instructional tasks. Thus the current study's findings confirmed and extended findings from the existing literature about the TPACK influence on ICT selection for classrooms.

Key Findings From Research Question 2

The current qualitative study developed from the problem of local biology teachers reporting challenges integrating ICT into their classrooms effectively. RQ2 was "What challenges do local public high school biology teachers experience in the integration of ICT into their biology classrooms?" Two key findings related to RQ2 emerged from the data. The first was that the biology teachers' challenges integrating ICT into their virtual classrooms related to infrastructural/technical issues such as technology or internet not working, and pedagogical challenges such as not enough time to complete the curriculum, and difficulty assessing students. The second key finding was that the biology teachers addressed challenges by using their internet and personal devices, training students in technology use, and in some cases collaborating with other teachers to share expertise. As with the decisions to select ICT tools for their virtual and blended classrooms, the teachers' mitigation of challenges involved their TPACK.

Challenges with ICT integration are often reported in the literature. Laronde et al. (2017) and Zyad (2016) explored logistical and infrastructural challenges to ICT integration and suggested that challenges could be mitigated by increased ICT provisions and upgrades. Effendi-Hasibuan et al. (2019) noted the challenge of a lack of equipment and facilities in Indonesian science classrooms. In other studies, Alemu (2017), and Fletcher and Nicholas (2018) noted inadequate resources and a lack of technical support as challenges to effective ICT integration into classrooms. Teachers in the current study cited many instances of infrastructural challenges such as inconsistent internet and electricity, and non-working devices. One of the ways teachers in the current study mitigated infrastructural challenges was by using their personal devices and their personal internet service to download content outside of class before bringing the downloaded and saved materials to class. By doing so, teachers demonstrated TPACK. Findings from my study confirmed and extended the existing literature on mitigating infrastructural challenges of integrating ICT into classrooms.

Pedagogical challenges related to ICT integration are also cited frequently in the literature, as are recommendations for mitigating the challenges. Plummer et al. (2021) stated that the virtual medium created challenges to student engagement and assessment of student learning. Teachers in the current study reported similar challenges, for example they shared about students' delinquency for online classes and students' non-submission of assignments on virtual platforms. Teachers in the current student noted that they created student-friendly virtual classrooms to encourage participation by calling students and reopening assignments frequently. The creation of student-friendly virtual classrooms was also recommended by Gerencer and Hayes (2020). Thus, the finding from the current study confirmed and extended the literature.

In their research Effendi-Hasibuan et al. (2019) noted challenges with using ICT effectively in large classes. Some teachers in the current study also noted the challenge of teaching large classes virtually (P2; P3; P4; P5). The teachers employed their TK and PK in collaborative practices that allowed effective engagement of those classes. Conrad and Donaldson (2012) cited similar solutions to the challenge of teaching large classes virtually. The data from my study confirmed and extended the literature on pedagogical challenges of integrating ICT into virtual classrooms with large numbers of students.

Magana (2017) and Zyad (2016) recommended that teachers mitigate some challenges to ICT integration by changing their pedagogical practices. Teachers in the current study struggled with teaching hands-on laboratory skills on virtual platforms, as also mentioned by Kavanagh et al. (2017), and Kapici et al. (2020). The teachers in the current study demonstrated TK and added to their PK by using virtual labs to teach the hands-on skills component of the biology curriculum. The virtual labs alternative to physical laboratories was also suggested by Alt (2018) and Hutchison (2018).

Data presented from the current study confirmed and extended findings from previous research on mitigating challenges of ICT integration into classrooms. However, how local teachers leveraged their TPACK into their virtual classrooms, adopted the new teaching platforms, and applied a positive mindset to helping their students succeed was the valuable extension of what was revealed in the literature.

Key Finding From Research Question 3

Research Question 3 was "What additional support, knowledge, or skills do teachers need to improve ICT use in their classrooms to positively impact student achievement in biology?" The key finding related to this RQ was that the ICT integration added value, and teachers wanted to improve their ICT use through additional in-school training and support, relevant ICT professional development, more teacher and community collaborations, and a unified government–teacher technology policy/plan that includes input from teachers' experiences with ICT in their classrooms.

Alemdag et al. (2020) and Mishra et al. (2019) posited that ICT integration into educational curriculum is valuable in transforming pedagogy and improving student learning. However, Hutchison (2018), Makransky et al. (2019), and Kara (2021) refuted the findings on improved student learning by reporting only modest improvements to student achievement from educational technology interventions. Teachers in the current study presented mixed views on whether their teaching in virtual classrooms added value for their students. Some teachers reported improvements in students' learning (P2; P5) although others disagreed (P3; P8). The agreements and disagreements voiced by the participants in the current study regarding the value of the remote teaching and learning initiative confirmed and extended the literature.

Studies on ICT integration into education invariably include suggestions or needs for improving the integration. Similarly, so for my research. PD/training in ICT for education was the first need identified by the biology teachers in my research. PD/training on ICT integration can influence teachers to transform their pedagogy (Alemdag et al., 2020; Mishra et al., 2019). In a 2020 study by Alemdag et al., teachers noted that they learned new ICT tools and new student-centered teaching methods in their PD workshops and improved their TK, and PK as a result of the workshops. Similarly, participants in the current study cited examples of attending in-school and government-provided workshops and seminars where they learned new ICT tools that enhanced their TK, improved their PK, and helped them transition to virtual teaching.

Sharick (2016) noted that ineffective PD leads to teachers' inability to transform their classrooms into student-centered foci. Participants in the current study suggested that school administrators and the MOEST continue to provide PD/training but make the training relevant to the biology content area. Alemu (2017) alluded to a lack of relevant preparation as a barrier to instructor's readiness and confidence in using ICT. Teachers in the current study shared that their ICT training frequently spanned several different subject areas and was therefore of little value to them as biology teachers. The irrelevant ICT training did not enhance the teachers' TK, or PK, as alluded to also by Sharick. The viewpoints shared by participants in the current study on the importance of, and need for, PD/training confirmed and extended findings from the literature.

The third need shared by the teachers in the current study was for teacher and other community collaborations to help improve teachers' TPACK and ICT resources in biology classrooms. Nwankwo and Njoku (2020) proffered that governments incorporate public–private partnerships to provide the critical infrastructure needed for effective technology integration. Similarly, P8 from the current study suggested that community partnerships could help provide needed ICT tools for teachers, and particularly for students who are economically disadvantaged in the shift to virtual learning. Participants in the current study opined that collaborations with other teachers could improve TPACK about what tools to use and how to teach in virtual classrooms. Harland (2020) referred to teacher collaborations or virtual professional networks (PN) as an untapped resource for teachers to gain pedagogical, technological, and emotional support. Harland suggested that educational researchers investigate and understand teachers' experiences building connectedness during the COVID-19 pandemic. My study's data confirmed and extended the findings in the literature.

The last, and the most often-cited need by participants in the current study was for a unified government–teacher ICT policy/plan. Participants in the current study opined that their experiences integrating ICT into remote classrooms needed to be considered in a revamped ICT policy/plan (P3; P8). Teachers in the current study iterated and reiterated their willingness to share their experiences to improve the biology curriculum and future ICT integration into biology classrooms. P3 from the current study noted that teachers' willingness to incorporate digital technologies into the new virtual platforms even though not well-prepared to do so initially, should be built on rather than overlooked by the government, education policymakers, and other educational stakeholders. Karadeniz and Thompson (2018) and Webster (2017) suggested that curriculum developers could gain insights on aligning ICT implementation with educational goals from teachers' experiences integrating ICT into their classrooms. Further, Nwankwo and Njoku (2020) posited the inclusion of teacher input into building local curricula content to enhance knowledge and skill acquisition. P8 noted that the Bahamian biology curriculum needed to be responsive to social change. Data from the current study confirmed and extended findings from the literature.

However, because there has been no previous research regarding ICT integration into Bahamian high school biology classrooms, my study's exploration of the teachers' ICT integration experiences and the itemization of their needs for improving the ICT integration into their classrooms not only confirmed and extended the literature but presented new findings for the Bahamian context. As in the extant literature, participants in my study cited needs for further in-school ICT training and support and PD/training specific to their subject area to improve their TPACK (see Alemdag et al., 2020; Sharick, 2016). Teachers in the current study indicated that they enhanced their TPACK from their virtual teaching during the COVID-19 pandemic and wanted to continue improving their TPACK to integrate ICT into future classrooms effectively.

Deciding on the Project Deliverable

I decided that data from the current study could be most applicable in the development of a position paper to inform local education policymakers and other stakeholders about necessary modifications for improving ICT integration in Bahamian public high school biology classrooms. Participants in the current study shared the challenges of integrating ICT into virtual biology classrooms and made recommendations for improving the remote education initiative. I included those recommendations, supported with similar recommendations from the existing literature, in the position paper

I developed. Implementation of the teachers' recommendations may improve pedagogy and students' biology achievement in virtual learning environments.

Conclusion

This current qualitative study explored teachers' ICT integration into local high school biology classrooms to address the problem of them experiencing challenges with the integration. The sample for this study was eight high school biology teachers involved in delivering the biology curriculum to their students in virtual and blended classrooms during the COVID-19 pandemic. Data collection consisted of virtual interviews with the teachers. Issues of credibility and validity related to the current study were addressed through the meticulous collection and verbatim transcription of interview data, keeping a log and reflective journal that influenced data collection, using a codebook to identify and clarify codes, allowing member checking and participant validation, and establishing a clear 'paper trail' between data analysis and the stating of results.

Analysis of the study's data yielded thought-provoking findings. The finding related to RQ1 was that teachers' decisions to use ICT were based on logistical reasons such as affordability and convenience of the ICT tools, teachers' technological knowledge such as familiarity with the ICT tools, and pedagogical reasons such as the helpfulness of ICT in facilitating instruction and assessment of student learning. Two findings related to RQ2. The first was that the challenges biology teachers experienced in integrating ICT into their classrooms related to infrastructural/technical issues, such as technology or internet not working, and pedagogical challenges such as the difficulty of assessing students on virtual platforms and insufficient time to complete the curriculum online. The second was that local biology teachers addressed challenges by using their personal internet and devices, training students on technology use, and collaborating with other teachers to share expertise. The finding related to RQ3 was that the ICT integration added value, and teachers wanted to improve the integration through additional in-school training and support, relevant ICT professional development, more teacher and community collaborations, and a unified government–teacher technology policy/plan that included input from teachers' experiences with ICT in their classrooms.

ICT is integral to the functioning of modern schools, and critically so during the current COVID-19 pandemic where schools have resorted primarily to technology-mediated virtual teaching and learning. No one can accurately predict when the COVID-19 pandemic will end. The best way forward for education in a COVID-19-impacted world is uncertain. This current qualitative study highlighted only a few teachers in a local setting who shared their experiences integrating ICT into their virtual classrooms during the COVID-19 pandemic and forwarded their viewpoints on improving the emergency remote education initiative. Giving credence to the local teachers' experiences with instructing and assessing students in a new virtual learning environment and with little preparation, could influence decisions about classrooms of the future. Results from the study indicated a need for a position paper, to raise awareness among education stakeholders about modifications for transforming pedagogy and improving student learning in future learning environments.

Section 3: The Project

The purpose of this current qualitative study was to explore teachers' ICT integration into the public high school biology curriculum in the Bahamas. I wanted to address the problem of the teachers reporting challenges with integrating ICT into their biology classrooms. I conducted the exploration during the COVID-19 pandemic when teachers were involved in delivering the biology curriculum to their students remotely. The project emerging from the study's findings was a position paper (see Appendix A). In developing the position paper, I situated my study within the parameters of the COVID-19 pandemic and searched within the existing literature for information related to the challenges of remote teaching and learning.

Situating the Local Problem

The onset of the COVID-19 pandemic forced unprecedented changes in education globally as education stakeholders scrambled to comply with health directives such as social distancing while providing mandatory educational opportunities for students. In many countries, remote instruction replaced traditional FTF instruction for students confined to their homes (The World Bank, 2020a). The measures labeled emergency remote education, have been described as nontheoretical and nonpedagogical and very different from the theoretically valid concept of distance education (Bozkurt et al., 2020).

In the Bahamas, the Prime Minister suspended FTF instruction in public schools on March 16, 2020, and virtual learning began shortly thereafter ("Prime Minister's Speech on COVID-19 in Full," 2020). Remote instruction began on October 5, 2020 for public schools and continued into the 2020–2021 academic year. On February 23, 2021, as the rate of COVID-19 infections appeared to slow, a blended classroom aspect was added to the virtual learning platform (Bowleg, 2021). I collected data for my study between May 11, 2021, and June 7, 2021. At the time of the interviews, my study's participants, who had experienced challenges integrating ICT into FTF classrooms before the COVID-19 pandemic, were experiencing additional challenges delivering the biology curriculum in virtual and blended classrooms during the pandemic.

Rationale

Findings from the current study confirmed and extended existing literature about the challenging nature of the new emergency remote instructional model. Participants reported infrastructural/technical challenges, such as inconsistent internet availability, and pedagogical challenges, such as assessing students and completing the curriculum remotely. Based on the current study's findings I considered two project genres as possible developments from the study.

Several of the study's participants cited the challenge of teaching and assessing hands-on biological skills on a virtual platform. Therefore, my first consideration of a project deliverable was the creation of an online resource to direct biology teachers to accessible ICT tools and suitable experiments for teaching and assessing the hands-on skills required by the biology syllabus on virtual learning platforms. The resource could be used in a PD workshop for teachers or accessed by individual teachers as needed. Teachers could benefit by acquiring knowledge about how to facilitate hands-on biological skills instruction with technology. However, I rejected this choice for two reasons. The first was that it might be challenging to develop PD because teachers are spread over the wide archipelago of Bahamian islands, although the PD workshop could be developed as a virtual activity. The second reason was that providing the resource would not address the broader problem of the challenges teachers reported with integrating ICT into their virtual and blended biology classrooms effectively.

I elected to develop a position paper to provide information about the teachers' many challenges integrating ICT into their remote classrooms during the COVID-19 pandemic, and also would present their recommendations for improving the ICT integration. The position paper could be useful in informing the government and education stakeholders about integrating ICT into Bahamian public school biology classrooms effectively. Positive social change could emerge from improved learning outcomes from implementing the teachers' recommendations in the position paper.

In the position paper, I provided a brief account of my study's findings and presented actionable solutions to the problem of teachers experiencing challenges with integrating ICT into their virtual and blended biology classrooms during the COVID-19 pandemic. I presented the teachers' recommendations and supported them from the existing literature on remote teaching and learning. I adopted a pragmatic approach of addressing the problems of transitioning to virtual and blended learning environments in a reasonable and logical way instead of depending solely on ideas and theories.

Review of the Literature

I conducted a literature search for information to validate the project, starting with Walden University's library databases and adding Google Scholar. I accessed multiple databases to gain a thorough overview of the extant literature on remote teaching and learning. I searched in academic journals for recent peer-reviewed articles, but because of the newness of the global transition to remote teaching and learning resulting from the COVID-19 pandemic, I concentrated my search from 2019 to the present. I also researched e-books, online newspapers and magazines, and web publications for information related to virtual teaching during that period. I referenced older literature only if they were seminal works. I searched by using keywords and Boolean phrases related to virtual teaching and learning such as *adopting virtual teaching*, *COVID-19*, *virtual LMS*, *transforming pedagogy*, *addressing technology issues*, *adapting curricula*, *teaching laboratory skills*, *virtual labs*, *virtual assessment*, *teacher-teacher support for virtual teaching*, *virtual learning communities*, and *emergency online learning policies*.

An important takeaway from the literature research and my study's findings is the challenging nature of virtual teaching and learning during the COVID-19 pandemic. However, there are solutions in the literature and from my study's exploration of teachers' experiences with integrating ICT into their biology classrooms during the pandemic. In the following sections, I highlight some of the challenges of remote teaching and learning identified in the literature and discuss some of the solutions to the challenges that were mentioned.

Infrastructural/Technical Issues

Internet Accessibility

Al Ghazali (2020) and Withers et al. (2021) noted the necessity of facilitating virtual learning in times of crises and emergencies like the COVID-19 pandemic by providing online self-access materials, proper technological infrastructure, fast internet connection, continuous power supply, and modern online platforms. Faced with the COVID-19 pandemic, many countries attempted to ease the transition into remote education by integrating digital technologies and non-tech technologies (The World Bank, 2020a). In Jamaica, initiatives included educational television lessons accessible on 25 cable channels, and printed learning kits for students without internet access (The World Bank, 2020a). Williamson et al. (2021) reported on WhatsApp being widely used for teaching during the pandemic in Argentina, where at the time of the current study less than 50% of students had access to a computer or quality internet connection, but most had access to mobile phones. Vu et al. (2020) noted that even without stable internet access kindergarten teachers in a rural U.S. school ensured that learning could continue by equipping students with needed paper texts and materials and conducting synchronous and asynchronous sessions with their young students.

Accessible Support for Troubleshooting Technology

Literature that addressed the strategies used to prepare teachers for emergency online teaching at the start of the COVID-19 pandemic was scarce. Teaching online without much preparation is a challenging experience (N. Johnson et al., 2020; Jung et al., 2021). Few articles that addressed the issue had been published, but they offered direction for the future. From an autoethnographic study of emergency remote education in a Japanese university, Jung et al. (2021) revealed that technical problems caused challenges with teaching online and engendered negative feelings in faculty. Jung et al. reported that faculty most often used their technological knowledge to resolve the technical issues, but in some cases relied on technical expertise from students. Sumer et al. (2021), in their ethnographic study of faculty in Australian, New Zealand, and Turkish universities, shared that representatives from departments within the universities provided the support to troubleshoot technical problems.

Dependability of Teacher/Student Devices

A big concern of ensuring remote learning for all students is the digital divide that may widen the learning gap between students and cause some to be unable to continue their education (Strauss, 2020). Strauss (2020) highlighted efforts to provide adequate digital devices and dependable internet service for disadvantaged students in parts of the United States. Withers et al. (2021) proffered similar strategies to address equity. Gerencer and Hayes (2020) and Pan (2020) suggested granting students access to remote classes on their mobile phones. Many students have mobile phones but do not have other digital devices (The World Bank, 2020a). However, online learning experts reject the idea that equal access to technology translates to student inclusion or success (Gerencer & Hayes, 2020; Pan, 2020; Withers et al., 2021).

Other Issues Affecting Students' Online Learning

Gerencer and Hayes (2020) and Pan (2020) posited that learning during the COVID-19 pandemic depended not only on providing devices but also on motivating students to learn on virtual platforms. Al Ghazali (2020) reiterated that learners' willingness and motivation were crucial and reinforcing them is necessary for learning to occur in virtual classrooms. Strategies for creating motivation include utilizing student-friendly virtual platforms and communicating clear expectations for students about course workloads, formats, deadlines, and other concerns (Gerencer & Hayes, 2020; Pan, 2020).

Bozkurt et al. (2020) noted that there are differences among teachers within schools and across schools in terms of digital access and digital literacies that affect the instruction students receive online. Gerencer and Hayes (2020) and Husain (2020) reported that teachers employed different strategies for facilitating instruction; therefore, students' grasp of content also differed. Gerencer and Hayes noted that students thrive on routine, without which they might see remote learning as an extended break with optional, occasional assignments; therefore, teachers should adhere to schedules and stated deadlines. Additionally, Withers et al. (2021) and Miller (2021) highlighted a need to examine psychosocial factors that affect students' academic performance during the COVID-19 pandemic.

Parental involvement is also a factor in the students' achievement (McCarthy & Wolfe, 2020; Williamson et al., 2021). Bozkurt et al. (2020) noted that with children learning from home, parents have suddenly had to learn how to become educators and balance job commitments with their children's learning. For effective partnership, the at-home learning plan must include the school's provision of consistent meeting schedules with times and links, student-focused instructions, and online and offline options for students to complete the activities (McCarthy & Wolfe, 2020). Building a learning community between students, parents, and teachers is essential for achieving effective virtual learning (Gerencer & Hayes, 2020; Husain, 2020). In essence, this means communication. For example, the literature revealed that teachers communicated digital learning expectations and procedures with students and parents (A. Koehler & Farmer,

2020) or called students by phone, sent letters home, and scheduled and kept virtual office hours to make personal connections with their online students (Miller, 2021).

Professional Development for Online Teaching

The need for teachers to have technological knowledge in addition to pedagogical and content knowledge or TPACK (see M. J. Koehler & Mishra, 2009) was accentuated by the shift to remote learning. Mucundanyi and Woodley (2021) proffered that TPACK could guide teachers in analyzing and selecting technologies that support pedagogy and engage students' learning. Training to equip teachers to integrate ICT into remotely delivered curricula effectively is essential (Al Ghazali, 2020; Nasr, 2020; Sumer et al., 2021). Shin and Borup (2020) reported on a global initiative in which webinars were used to help English language teachers quickly design and facilitate synchronous and asynchronous online remote instruction. Shin and Borup shared that teachers in their study felt the training came right when it was needed. Bozkurt et al. (2020) posited that unless teachers possess the technological competence to use the tools effectively, investing in hard technologies such as broadband internet, computers, and mobile technologies would not create success stories. Further, Bozkurt et al. recommended a harmonization of teachers' soft skills and digital competencies for implementing emergency remote education successfully.

PD for teachers should include training on how to create digital learning plans for implementing teaching on online platforms (A. Koehler & Farmer, 2020). A well-developed digital learning plan communicates procedures and expectations regarding online learning for students, guardians, teachers, and administrators and can allow instruction to continue during disruptive circumstances (A. Koehler & Farmer, 2020). According to Sumer et al. (2021), teachers need to learn the pedagogical differences between FTF and online teaching; otherwise, they might transfer their FTF teaching habits to distance learning systems. Sumer et al. posited that education stakeholders appeared to be trying to cope with the COVID-19 pandemic situation rather than working on a well-planned pedagogically sound educational plan. Faculty in Sumer et al.'s study were provided with online resources and classes to equip them for remote teaching, but for many other teachers little or no training was provided (N. Johnson et al., 2020; Jung, et al., 2021). Harland (2020) purported that teachers may have explored virtual avenues for PD on their own, and therefore educational researchers have a responsibility to seek out and understand teacher experiences (p. 304). Training for online teaching could help teachers develop engaging eLearning experiences and remove distractions and confusion (A. Koehler & Farmer, 2020).

Learning Management Systems and Training

Teachers working remotely can access several LMSs such as Blackboard, Moodle, and Microsoft Teams to manage online courses. LMS affordances include providing course content, delivering class announcements, recording synchronous and asynchronous class sessions, facilitating class discussions and assessments, and communicating with learners (Ahshan, 2021; Canipe & Bayford, 2020; Chow et al., 2018). Data from Ahshan's (2021) study on LMSs revealed Moodle as an effective eLearning platform. However, all LMSs have not been proven effective. From their study van Wyk et al. (2020) revealed that the LMS used by teachers was not very effective because the platform was sometimes unstable and the content was sometimes insufficient; teachers often had to add content and activities to the platform.

At the start of emergency remote teaching, few teachers were trained in online teaching (N. Johnson et al., 2020; Jung et al., 2021) although LMS training had been proffered as a key strategy for overcoming challenges of remote teaching (Chow et al., 2018). From a study examining teachers' LMS use in a university Chow et al. (2018) reported that LMS training enabled teachers to change their pedagogical use of LMS tools. Moreover, teachers who received LMS training showed a greater frequency and diversity of technological tool use than untrained teachers (Chow et al., 2018).

Teacher–Teacher Networks and Other Partnerships

A report of responses in 31 countries suggests that for many education practitioners, collaboration and sharing were among the primary reactions to the first phase of the pandemic (Bozkurt et al.). In their study about virtual teaching Withers et al. (2021) described a partnership between a Global Health Working Group on Education and Technology and a university to provide pedagogical technology, and peer support to faculty who were facing remote teaching challenges. Sumer et al. (2021) iterated the importance of teachers in online teaching contexts finding peer support that may help to solve challenges and reduce fears and inconveniences of virtual teaching. Co-planning, co-teaching and co-assessing within similar disciplines have been advocated as solutions for pedagogical challenges of teaching online (Golloher et al., 2020). Harland (2020) alluded to the distinct possibility that teachers who are teaching in physical isolation may reach out virtually to their colleagues for support. Canipe and Bayford (2020) noted that tapping into this crowd-sourced wisdom was a good strategy for teachers to improve remote instruction instead of facing the challenges alone.

Additionally, partnerships between education stakeholders and community organizations can provide support and services, such as internet hotspots inside and outside of school buildings (Strauss, 2020). In various cities in the United States, businesses and philanthropic organizations made financial contributions to school districts to help improve remote-learning accessibility (Strauss, 2020). Withers et al. (2021) reported on the creation of a program at the University of the Philippines to seek financial support from alumni, civil society, and donors to fund equitable remote learning for all students at the university.

Adapting Curricula and Assessments for Emergency Situations

A challenge of teaching in virtual environments is gauging students' content grasp before summative assessment (Withers et al., 2021). Al Ghazali (2020) suggested that educational authorities improve the educational content and adapt syllabi and assessment techniques within the limitations of COVID-19 restrictions. To ease the load on educators and learners in virtual environments, many institutions have reduced curricula and evaluation methods, for example by emphasizing formative over summative assessments (Bozkurt et al., 2020; Gonzalez, 2020). Gonzalez (2020) proffered that changing the focus on summative assessments gives students "wings of choice and voice." In a pre-COVID-19 article Hamilton (2018) highlighted non-traditional methods of demonstrating student learning with technology, for example, by creating projects, conducting research, solving problems within content areas, accessing interactive websites, interacting with people around the globe, building a web presence, and producing videos. Hamilton iterated that students learn when they participate in learning, by exploring ideas and connecting them to what they already understand, and creating ways to share their knowledge with others. Therefore, allowing students to use non-traditional assessment methods that involve active participation will increase their learning (Hamilton, 2018). However, the integrity of online assessments is an area of continued discussion. Withers et al. proposed a strategy of using summative assessments with open-ended questions where students synthesize knowledge rather than regurgitate facts. In that way, there is more of a certainty that students' answers are their own.

Yet, some traditional assessment methods appear to work better in online courses than in FTF classrooms. Withers et al. (2021) noted that questions posed in an online chat can be responded to by many students, whereas time limits in a synchronous FTF class would allow only a few responses. Moreover, Withers et al. reported that students who are hesitant to raise their hands in FTF classes were more likely to type a response to a question in an online class and their responses were apt to be more candid.

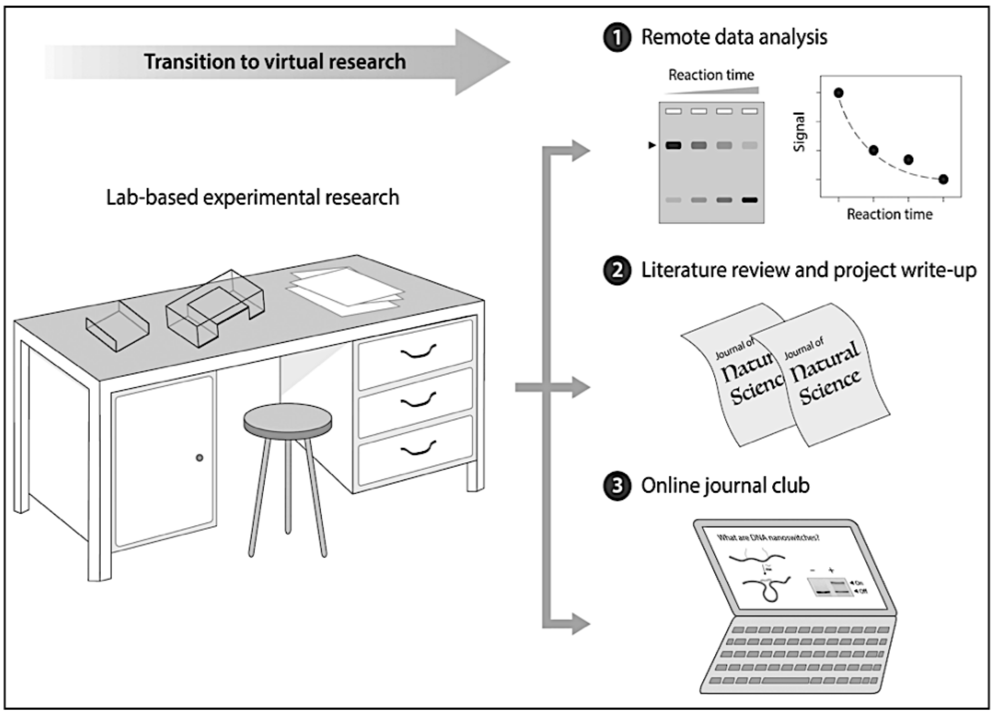
Al Ghazali (2020) suggested that educational authorities accept teachers' autonomy and offer them flexibility to make instructional and assessment modifications. Withers et al. (2020) recommend that academic institutions redesign courses to an online format and record class sessions so they are accessible to students who are unable to participate synchronously. Conversely, other researchers posited that curricula do not need to change, just presented in multiple forms, for example, by adding interactive activities that encourage student participation (Gerencer & Hayes, 2020; Kapici et al., 2020; Pan, 2020). Bozkurt et al. (2020) and Nasr (2020) proffered a reduced focus on curricula, stating that the COVID-19 pandemic has shown the need for a pedagogy of care over a need to teach the curriculum. Now, more than ever before, educators are advised to think beyond learners' roles in the classroom to the difficulties they may be facing in their personal lives during the pandemic (Bozkurt et al., 2020; Nasr, 2020). Therefore, teachers should demonstrate flexibility with their online students, for example, relaxing deadlines, or excusing instances of non-participation in synchronous classes when students experience family crises, or study in less-than-ideal learning environments at home (Canipe & Bayford, 2020; Nasr, 2020; Withers et al., 2021).

Teaching Scientific Skills Remotely

In FTF instructional modalities, students learned scientific skills, such as suggesting hypotheses, designing and conducting an experiment to test a hypothesis, collecting and analyzing data to get results, evaluating the results and making inferences, by conducting experiments in physical laboratories (Tsichouridis et al., 2019). However, the onset of remote learning at the start of the COVID-19 pandemic meant that science laboratories in brick and mortar schools were no longer accessible to students (Chandrasekaran, 2020; Kapici et al., 2020; Tsichouridis et al., 2019). Yet for science instruction the traditional concept of using laboratory exercises to supplement and reinforce science concepts remained (Guzmán & Joseph, 2021). Paxinou et al. (2020) noted that although physical laboratories offered critical ingredients in science learning, non-access to those laboratories meant that there was now a need for students to learn science through innovative technology use. Figure 4 shows Chandrasekaran's (2020) graphical representation of the transition.

Figure 4

Transition to Virtual Research



Note. This model was produced by Chandrasekaran in 2020, representing ways that undergraduate students in science research programs can be engaged online through remote data analysis, literature review, and journal club presentations. From "Transitioning undergraduate research from wet lab to the virtual in the wake of a pandemic," by A. Chandrasekaran, 2020, *Biochemistry & Molecular Biology Education*, *48*(5). 436–438. Reprinted with permission (see Appendix C).

Theoretically, virtual labs can allow students engaged in remote learning to experiment in science (Guzmán & Joseph, 2021; Nasr, 2020; Wright, 2020). Virtual science lab activities include not just watching a lab, but navigating the activity and responding to discussion questions (Wright, 2020). Research on the efficacy of the intervention is ongoing though much of the research is at the tertiary education level.

In a study where engineering students used virtual labs, Achuthan et al. (2021) found that remote users conducted experiments three times more frequently and completed assignments faster than in physical labs, but this was during the COVID-19 pandemic when physical lab access was restricted. Nasr (2020) noted that The Concord Consortium provided an online platform for STEM learning resources and modules that promoted online learning experiences that engaged students with science practices such as collecting and analyzing data, using models, and justifying conclusions from evidence. Nasr reported that students enjoyed the activities and expressed a sense of achievement from successfully navigating the modules. In another study by Kapici et al., 2020) a majority of middle-school students in a US public school stated that designing and conducting experiments in a virtual laboratory environment was easier than in a hands-on laboratory, though some students had difficulties writing laboratory reports.

There are criticisms related to virtual labs. Brown (2020), and Mahaffey (2020) noted that students were not connecting virtual science experiments with real life. To mitigate a reputed lack of interaction with the natural environment, Brown (2020) created an authentic, outdoor, exploratory assignment where students documented their observations and augmented the activity by watching videos online. Guzmán and Joseph

(2021) created an authentic virtual lab on anaerobic digestion for their college engineering syllabus, with the added benefit of being easily accessed on laptops, tablets, and smartphones and downloadable for offline use.

In light of criticisms about the non-relevance of virtual labs and challenges of inaccessibility that sometimes relate to cost, some teachers consider that a balanced use between hands-on laboratory activities and simulated virtual labs might be the best choice for acquiring scientific skills (Tsichouridis et al., 2019). Balancing hands-on and virtual laboratory experiences could involve science experimentation at home and sharing results on a virtual bulletin board (Chandrasekaran, 2020; Wright, 2020). Wright suggested that teachers use online data sets such as local tide charts, rain charts, and environmental temperature and landscape changes to get students to analyze scientific data. The virtual lab alternative to wet labs can provide student engagement as well as a scale to grade students in the absence of traditional science laboratories (Chandrasekaran, 2020).

Project Description

I conducted a qualitative study to explore teachers' ICT integration into Bahamian public high school biology online and blended classrooms during the emergency remote education initiative forced by the COVID-19 pandemic. Data from the study revealed many challenges with teaching and learning biology on the online and blended platforms. However, biology teachers who were participants in this current study provided recommendations to solve the challenges. I developed a position paper (see Appendix A) as the project deliverable from my study. My goal in developing the position paper was to present education policymakers and stakeholders in the Bahamas biology teachers' recommendations for improving teaching and learning on virtual platforms.

To complete Section 3 of my project study manuscript, I discuss my plan for implementing the position paper. I include a description of needed resources and existing supports, potential barriers and possible solutions. Finally, I present my plan for evaluating the success of the position paper's implementation.

Position Paper Implementation

Immediately after Walden University's Chief Academic Officer's acceptance of my project study, I assume the role of presenting the position paper (Appendix A) to the Director and Deputy Director of the Ministry of Education and Technical and Vocational Training (MOETVT). I anticipate doing this early in 2022. Because of COVID-19 social distancing restrictions, I will email the position paper rather than present it in person. I will request the Director of Education share the position paper with the Minister of Education, and the Permanent Secretary at the MOETVT. If the educational leaders at the MOETVT want an in-person meeting with me, I will suggest in my email that they request one. I will make myself available for an in-person meeting if needed. Implementation of the position paper will now rest with the MOETVT. It will be the responsibility of the educational leaders at the MOETVT to make any decisions related to the biology teachers' recommendations for improving remote learning in the Bahamian setting. I am optimistic about the position papers' implementation.

After presenting the position paper, I will periodically reach out by email to the Director of Education to learn if progress has been made on its implementation. If the answer is in the affirmative I will attempt to determine from biology teachers the extent of implementation of the recommendations outlined in the position paper. I will do this by conducting online and paper surveys among biology teachers in Bahamian public high schools. I will survey more than just the eight biology teachers who were involved in my study. At the time I conduct the surveys I will want to determine if all teachers have access to adequate digital devices and supportive infrastructure for online and blended teaching and learning. I will want to know whether teachers have been invited to liaise with the MOETVT to create a sustainable educational plan, have received relevant PD/training for remote teaching, and provided an online resource for teaching hands-on biological skills remotely. I will want to know if there have been amendments to the biology curriculum and to the BGCSE biology examination format.

Needed Resources and Existing Supports

The goal of improving teaching and learning in virtual biology classrooms in the Bahamas during the COVID-19 pandemic is unachievable without some needed resources. I identified several requisites based on the current study's data and the participants' recommendations for improving the remote education initiative, which I have outlined in the position paper. A centralized, functional LMS to support remote teaching and learning is an urgent need. A central online portal can include a consolidated listing of available content, tools, apps and platforms, together with support materials and guidance for students, teachers and parents (The World Bank, 2020b). Teachers and students need adequate digital devices to access and work online and reliable infrastructure for supporting the devices. Technical support for troubleshooting technology problems needs to be available and easily accessible to teachers and students. Creating an online resource to assist teachers in remotely teaching hands-on biological skills is an urgent need, as is the provision of subject-specific PD workshops that highlight ICT tools and pedagogical uses in a remote learning environment. There is also a need to train students on how to use technology for learning. Students need how-to directions for accessing and navigating online learning platforms successfully.

Some supports that may facilitate successful implementation of the position paper already exist in schools. Most schools have internet availability, though reportedly inconsistent, so teachers can potentially work online from their schools. Many students have digital devices so they can learn from home. Many teachers have TK and PK about applying ICT for instruction and assessment of student learning, and have therefore been able to adapt to the emergency remote education initiative.

In the position paper, I have offered myself as support for the implementation, particularly in developing the online resource for teaching the hands-on biological skills component of the biology curriculum. However, I consider the best support for successful implementation of the position paper comes from the biology teachers' motivation to adopt the remote teaching initiative at the onset of the COVID-19 and to improve it during the pandemic and beyond if necessary. As P8 from my study stated "we did it when we didn't have to do it. I think it was optional" and "we need to continue that transition into going digital."

Potential Barriers and Solutions

I do not expect the position paper's implementation to be seamless, nor automatically successful; accepting new ideas or innovations rarely is (Magana, 2017; Serdyukov, 2017; Stowell et al., 2018). There are several potential barriers to the successful implementation of the position paper. Potential barriers include budgetary concerns related to providing digital devices and supportive infrastructure, some teachers' negativity regarding the emergency remote education initiative, and issues involving education policymakers and stakeholders. Some barriers may prove easier to overcome than others. In Table 13, I identify some potential barriers and describe possible solutions for each barrier.

Table 13

Potential Barriers and Possible Solutions for Project Implementation

Potential barrier	Possible solution
MOETVT's disinterest in my study's findings or recommendations	No solution. Despite possible disinterest, I will continue to argue that the teachers' recommendations, which are supported by research in the field, are worthy of consideration in developing a sustainable education plan that can withstand the challenges of the ongoing COVID-19 pandemic.
Cost and resources	An increased education budget to provide resources and training for administrators, teachers, students, and parents (Effendi-Hasibuan et al., 2019). Providing adequate digital devices and supportive infrastructure for teachers and students (Strauss, 2020; Withers et al., 2021).
Lack of administrator support	Informing administrators about remote learning best practices; providing information to administrators on how to support teachers and students in remote learning environments (N. Johnson et al., 2020)
Communication failure between MOETVT and teachers	MOETVT 'checking' in with teachers periodically to discuss how the remote teaching is progressing. Increased 'round-the-same-table' conversations that help to develop best strategies for remote education.
Lack of technological and pedagogical knowledge	Relevant PD/training to equip teachers to integrate ICT into remotely delivered curricula (Al Ghazali, 2020; N. Johnson et al., 2020; Sumer et al., 2021).
Some teachers' resistance; lack of buy-in	PD/training to familiarize teachers with technology (Ervin-Kassab, 2020). On-time technical support to troubleshoot problems (Sumer et al., 2021).
Students' absenteeism and disengagement	Training on how to use technology for learning; equal digital access; supportive infrastructure for learning at home; personalizing the remote learning experience to increase engagement (Al Ghazali, 2020; Gerencer & Hayes, 2020; Kara, 2021).
Parental non-support	Communicating with parents; sharing the students' schedules and tasks for remote classes; partnering with parents (A. Koehler & Farmer, 2020; Miller, 2021; Vu et al., 2020)

Project Evaluation Plan

I selected an outcomes-based evaluation plan for the position paper. Serdyukov (2017) noted the applicability of students' formative and summative examination scores to evaluating the effectiveness of educational innovation. The effectiveness of educational innovation is sometimes evaluated on other factors such as productivity and time-efficiency (Serdyukov, 2017). The evaluation plan for the project developed from this current study will involve determining the effect of implementing the project's recommendations on improving students' biology scores.

Strategic stakeholders in the project evaluation plan are educational leaders at the MOETVT and schools, teachers, and students. If the MOETVT does not implement the recommendations of the position paper, a consideration of its success becomes a moot point. If administrators receive no training for remote learning, continue to evaluate teachers on previous FTF classroom criteria, and offer no support to teachers using online platforms, teachers will remain frustrated and unable to teach effectively in their remote classrooms. If the MOETVT does not act on teachers' recommendations outlined in the position paper, ineffective remote instruction will continue, and students' learning in online classrooms will likely not improve. Kara (2021) referred to emergency remote education as a plan to provide "disrupted classes, undisrupted learning through virtual platforms" during the COVID-19 pandemic (p.1). Disrupted learning in a COVID-19-disrupted Bahamas is the likely outcome for students if the recommendations of the position paper are not implemented.

In evaluating the success of the implementation of the position paper, I will focus on the students' biology achievement after the implementation. Although I will not have access to internal school data from formative and summative assessments, I can access publicly available data on schools' national examination results in biology from the MOETVT's Testing and Assessment Department. I will compare pre-test and post-test data to determine improvement in students' biology scores.

However, I am cognizant that changes in student scores might not be immediately apparent. The Bahamian biology curriculum spans 3 years. Biology scores for students entering Grade 10 become available only after the students sit the national biology examination in Grade 12. For Grade 11 and 12 students, improved biology scores might not be attributable to the position paper's implementation, because the Grade 11 and 12 students would have experienced ideal online learning conditions for just one or two years. Furthermore, additional research will be needed to ascertain if improvements in students' biology scores can conclusively attributed to the implementation of the position paper's recommendations or involve other factors.

There are two other methods I can apply to determining the successful implementation of the project. Congruent to evaluating student outcomes, I can evaluate teachers' satisfaction with delivering the biology curriculum online after the implementation of the position paper. Increased teacher satisfaction could make a significant impact on improving students' learning outcomes. I can ascertain teacher satisfaction by conducting online surveys. It might be worthwhile also to perform learning analytics by collecting data about the students' experiences learning remotely.

The data could be a good reflection of student engagement and motivation for online learning, thus reflecting successful implementation of the project.

Project Implications

Implementation of the recommendations outlined in the position paper could improve ICT integration into the Bahamian public high school biology curriculum. The position paper's recommendations could also influence policy decisions on ICT integration into Bahamian schools at various academic levels and for different curricula. The current research could be a catalyst for positive social change as policymakers and education stakeholders might be better informed about the need for possible curricula modifications, PD/training, and collaborative decision-making to improve educational offerings. Social change could also develop when teachers are provided with knowledge about using new technologies and can incorporate the technologies into the learning process effectively. The project could be of particular importance in helping to provide the best educational offering for students in the Bahamas during the COVID-19 pandemic. The current pandemic accentuates the critical need to effectively integrate ICT to produce the best learning environments for today's classrooms and classrooms of the future. The study's findings might be transferable from the local Bahamian setting to the global educational profession.

Section 4: Reflections and Conclusions

In this final section of my study, I discuss the project's strengths and limitations in addressing the problem and refer to appropriate literature. I describe alternative approaches to addressing the problem and alternative solutions. I present reflective analysis about personal growth as a scholar, practitioner, and project developer specific to the research and project development. I also reflect on the importance of the work and what was learned. I describe the potential impact of the project for positive social change and discuss the project's importance to local stakeholders and the broader educational field. I outline possible directions for future research. Finally, I conclude with a review that captures the key essence of this current study.

Project Strengths and Limitations

Project Strengths

The position paper (see Appendix A) that I developed as the project deliverable for my study reflects several areas of strength. In the position paper I revealed some of the problems my study's participants experienced integrating ICT into virtual and blended classrooms during the COVID-19 pandemic. However, the position paper does not just reflect doom and gloom. Instead, the teachers' recommendations are actionable and immediately implementable, reflecting an optimistic approach to solving problems with the emergency remote education initiative. In the position paper, I noted positive outcomes reported by teachers, particularly the increased TK, PK, and collaborative skills that could improve virtual instruction in the Bahamian public school educational setting.

Teacher satisfaction with virtual instruction, as well as student learning outcomes, may improve after the implementation of the position paper's recommendations.

The strength of the position paper also lies in the fact that evidence of problems integrating ICT effectively into delivering the biology curriculum on remote teaching and learning platforms in Bahamian public high schools derives solely from the study data. The evidence is provided as participants' direct quotes or paraphrases of their statements. Taking the teachers' positions and supporting their stances with evidence from the study and existing literature contributed to a robust position paper (see "Writing a Position Paper," n.d.). The teachers' recommendations for improving the initiative are valid because they reflect the recommendations of other researchers in the field. Table 14 shows some of the teachers' recommendations contained in the position paper along with citations of similar recommendations from extant literature.

Table 14

Teachers' Recommendations Matched With Literature Citations

Teachers' recommendation	Literature citation
Adequate digital devices and supportive infrastructure	Effendi-Hasibuan et al., 2019; Gerencer & Hayes, 2020.
Research on students' nonparticipation in virtual classes	Bozkurt et al., 2020; A. Koehler & Farmer, 2020; McCarthy & Wolfe, 2020; Miller, 2021; Williamson et al., 2021; Withers et al., 2021.
PD/training for teachers	Al Ghazali, 2020; Mishra & Koehler, 2006; Nasr, 2020; Serdyukov, 2017; Sumer et al., 2021.
Curricular amendments	Al Ghazali, 2020.
Amendments to ICT policy/plan	Williamson et al., 2021; Zagami et al., 2018.
Empathic support	Bozkurt et al., 2020; Williamson et al., 2021

Project Limitations

There are limitations relating to the project deliverable for this current study. Having an extended time frame for determining the project's successful implementation is a limitation. The biology curriculum spans 3 years, so students' national biology scores reflect 3 years of instruction. Schools' internal biology scores from formative and summative assessments administered on a year-to-year basis could provide quicker data to determine successful implementation, but I have no access to that data. A further limitation is the potential for erroneously attributing any improvement in students' learning outcomes solely to implementation of the position paper.

Recommendations for Alternative Approaches

Alternative Approach

The purpose of this qualitative study was to explore biology teachers' reports of challenges integrating ICT into virtual and blended classrooms in Bahamian public high schools. A qualitative approach was appropriate because of the small pool from which I could draw participants for the study. I collected textual data from eight biology teachers during online interviews. An alternative data collection method could have been through online surveys, but I decided against this approach. Surveys would not have allowed me to talk with teachers nor enabled the participant–researcher rapport that resulted in interviewees sharing deeply with me their remote teaching experiences. Although a survey might have generated more participants than the eight I received, I was not granted access to email contact information for many biology teachers. Moreover, judging by the poor response from recruitment flyers distributed in schools, a request to participate in a survey could have also generated a small number of responses.

Alternative Solutions

The consideration of alternative solutions to the problem of teachers experiencing challenges with remote teaching during the COVID-19 pandemic pushed my knowledge application and tested my creativity. I thought about ICT's usefulness in facilitating teaching and learning. Also, I considered the challenges that teachers in my study were experiencing integrating ICT into their classrooms. I read and synthesized emerging literature on emergency remote education and considered the pathways and perspectives reported by researchers in the field.

Several teachers in my study reported the challenge of teaching hands-on biological skills remotely. After examining the corpus of data, I confirmed that there was a problem teaching hands-on biological skills in the absence of physical laboratory access due to school lockdowns during the COVID-19 pandemic. Teachers attempted to solve the problem by using virtual labs in place of physical laboratories. However, teachers also reported that using virtual labs did not solve the problem because some virtual labs were cost prohibitive and did not always provide activities that applied to the Bahamian high school biology curriculum. Also, allowing students to sit an additional written Paper 5 in place of the hands-on biological skills component of the national biology examination did not solve the problem

I considered developing an online resource for teaching hands-on scientific skills on a virtual platform as my first approach to solving the problem. In developing the resource, I could apply knowledge and expertise gained from teaching biology and my many years as the chief marker responsible for vetting students' scores for the hands-on skills component of the Bahamas national high school biology examination. I could provide an online resource bank of experiments that could help students learn the hands-on skills required by the biology curriculum, even in online classrooms.

However, I realized that the biology teachers reported many challenges in delivering the biology curriculum remotely, and the online biology resource would address only one of those problems. I opted to develop the position paper (see Appendix A) to present teachers' recommendations to address the many challenges of teaching remotely during the COVID-19 pandemic. The creation of the position paper would be a more effective solution than the online resource. In the position paper, I included a recommendation that the MOETVT appoint a team of their technology-competent staff and educators with expertise in teaching hands-on biological skills to develop the resource. I produced an example (see Appendix B) of an online laboratory activity that could provide an exemplar for the resource team if they should choose to develop additional resources for biology teachers. I noted that the resource could be used as a PD training tool or accessed by teachers as needed. In the position paper, I noted my willingness to lend my support in this area or any other.

P8 from my study forwarded another approach to solving the challenges of teaching remotely during the COVID-19 pandemic. The proposed solution is to provide an online space where biology teachers can meet to discuss the challenges with the emergency remote education initiative and present their solutions. The biology teachers could share the ICT tools they used and the topics for which ICT tools were helpful. In proffering the solution, P8 stated “I think that alone can be the basic structure of how we can now move to this digital curriculum.”

Scholarship, Project Development, and Leadership and Change

Personal Growth as a Scholar

As I reflected on my journey toward a doctoral degree, I identified several areas of growth as a scholar. I honed my research skills while planning academic research, conducting the research, collecting data to answer research questions, and presenting the data to establish a clear paper trail to my study’s findings. I learned how to code data manually and with the aid of Dedoose qualitative data management software and how to critically analyze my study’s data to confirm the validity of my findings. I became knowledgeable about accessing and examining scholarly literature to situate my study within previous research and establish the relevance and significance of my research. I discovered that examining academic literature revealed the etiology of related research and helped guide my study (see Ravitch & Carl, 2016). I learned to consider the findings from previous research to situate my study’s findings within the current understanding in the field of educational technology (see Ravitch & Carl, 2016; Yin, 2016).

I started this doctoral program with proficient writing skills, an often-cited prerequisite for successful online learning. However, completing my doctoral project study has improved my writing skills tremendously. My writing has evolved through many iterations as I learned to write with clarity, preciseness, and conciseness. I learned patience as I polished draft after draft for submission and critique. I eventually learned to accept criticism with grace because the feedback improved my writing and extended my sometimes narrow perspectives on my research. I also learned to accept praise for work that was well written and reflected broad considerations about my research.

Personal Growth as an Education Practitioner

In fairness, I cannot say that my doctoral journey at Walden University has made me a better education practitioner because I am not presently an actively practicing educator. However, I have gained expert knowledge about remote teaching and learning. I have improved my digital scholarship and am now well equipped to participate in emerging academic, professional, and research practices that depend on digital systems. My ICT literacy has improved, too. I am more competent in adopting, adapting, and using digital devices, applications, and services. Thus, I personify Walden University's definition of a scholar-practitioner. I know how to apply scholarly research and knowledge to practice (Walden University, 2018).

Personal Growth as a Project Developer

I grew as a project developer too. In developing the position paper, I became a strong advocate for change. I presented the teachers' recommendations clearly and in many instances included direct quotes to support the suggestions. I presented firm arguments for accepting and implementing the teachers' recommendations for improving teaching and learning in their virtual and blended classrooms in the Bahamas. I established credence for the teachers' recommendations by providing similar recommendations from the burgeoning field of virtual education. I honed my leadership skills and became a repository of knowledge about online teaching and learning. The knowledge gained might be applicable in a consultative capacity as policymakers and stakeholders seek a sustainable education plan for the Bahamas.

An unforeseen takeaway from conducting my study and developing the project was developing empathy for the participants. As I collected and analyzed data for my study, I probed the participants' words and the nuances of each conversation. I grasped the teachers' frustrations as they reported the many challenges in delivering the biology curriculum to students during the COVID-19 pandemic. I was humbled by how openly the teachers shared their experiences with emergency remote teaching. I was impressed with the teachers' ICT use for instruction and student assessment, even though they had received little training for online teaching before beginning emergency remote instruction. I adopted the teachers' stance on the need for openness in education through collaboration between policymakers and teachers in decision making. Taking the teachers' position and supporting their stance with evidence from my research and existing literature contributed to a robust position paper (see "Writing a Position Paper," n.d.). However, in hindsight, empathizing with my study's participants might have been inadvisable because developing the project was emotionally and physically draining.

Reflection on the Importance of the Work

The purpose of my qualitative study was to explore teachers' ICT integration into Bahamian public high school biology classrooms during the COVID-19 pandemic. Because of closed FTF classrooms necessitated by the COVID-19 pandemic, the classrooms were either fully online or blended. Analysis of interview data for codes and themes revealed several emergent themes and four key findings (a) ICT selection hinged on logistics and teachers' technological and pedagogical knowledge; (b) teachers experienced infrastructural, technical, and pedagogical challenges; (c) teachers found solutions for the challenges; (d) the ICT integration was valuable, and teachers wanted to improve their ICT use to enhance their teaching and students' learning in remote classrooms. The project that was developed from the current research was a position paper (see Appendix A) to present education policymakers and stakeholders in the Bahamas teachers' recommendations for improving remote teaching and learning.

I posit that the research I completed is significant and implementation of the project is crucial to improving teaching and learning in remote classrooms in the Bahamas. Emergency education measures during the COVID-19 pandemic did not appear to benefit students greatly (Rolle, 2021; The World Bank, 2020b). The best way forward is undetermined (N. Johnson et al., 2020; The World Bank, 2020b). Vital information is emerging from research in the field of remote teaching and learning. My research findings may contribute to the growing body of knowledge about virtual teaching and learning. Implementation of the position paper may provide knowledge, skills, and tools for teachers' effective facilitation of learning in online and blended classrooms. If teachers feel better supported, students may gain better opportunities to continue learning despite closed physical classrooms during the COVID-19 pandemic.

Implications, Applications, and Directions for Future Research

Implications and Applications

The position paper I created as the project deliverable from the current study has implications for social and educational change. The position paper may inform education policymakers and other stakeholders about modifications that may better support teachers delivering the biological curriculum on virtual platforms in the Bahamas. The position paper could be a catalyst for social change by providing teachers with strategies for improving instruction and student assessment on virtual education platforms. Effective virtual classrooms could improve learning outcomes for students as their education continues without disruption during the COVID-19 pandemic (Kara, 2021). Social change may accrue as students continue to receive educational opportunities that equip them to fulfill their potential to be change makers in society. The position paper could have relevance in the global education arena, where countries seek a sustainable education plan for the COVID-19 pandemic and beyond. The position paper could be an example of *glocalization*, an interplay between local, regional, and global interactions (Willems & Bossu, 2012). The research conducted with teachers in the Bahamian setting might inform teachers in the Caribbean region and around the world about the unique challenges of virtual biology instruction. Butler et al. (2018) alluded to the need to "support the educational, social, and economic transformation necessary for the complex global world of today and tomorrow" (p. 1).

Directions for Future Research

The COVID-19 pandemic spurred the adoption of emergency remote learning to provide uninterrupted education for students through virtual platforms (Kara, 2021). However, many countries did not achieve the objective of providing uninterrupted education for students. For example, in the Bahamas, the Director of Education reported that approximately 30% of students did not show up for online learning (Scott, 2021). This referred to nearly 15,000 of the approximately 50,000 registered students.

Emergency remote learning, though enabling the continuation of education for many students during the COVID-19 pandemic, does not appear to be a long-term solution (N. Johnson et al., 2020; The World Bank, 2020b). There is a great need for further research on the efficacy of remote teaching and learning for all educational levels. More data on emergency remote teaching and learning initiatives need to be collected and analyzed, not only for tertiary level education where there has been much recent focus but also at K-12 levels. Best strategies for remote teaching and learning need to be discovered and adopted. The recently-appointed Minister of Education in the Bahamas' MOETVT emphasized these needs. In a House of Assembly address on October 26, 2021, she said that her ministry "must get a data-driven evidence-based understanding of the implications of the pandemic and the disruption it has caused" (Rolle, 2021). The Minister of Education also said that collecting the data "is critical so that we may swiftly implement strategically-targeted remedial interventions to reverse or minimize the damage caused by the disruption of education" and that the task ahead is "monumental" (Rolle, 2021). I suggest a few possibilities for future research on remote teaching and learning in the Bahamian setting.

My research involved only eight biology teachers in Bahamian public high schools. Broader research in the local setting could involve exploring the remote teaching experiences of science teachers at junior and senior schools, rather than only the biology teachers at the senior-school level. The study's participants would comprise biology, chemistry, physics, and combined science teachers in senior high schools and general science teachers in junior high schools, thus targeting a broader participant pool. The research could explore several areas of remote teaching, such as the online and offline activities teachers gave, what worked well, the challenges teachers experienced, and how to improve the remote science instruction process. Another area of research is exploring how teachers interacted with each other during virtual teaching and what insights were collectively developed about the future of teaching and learning (Harland, 2020).

Another research possibility is to explore the student perspective related to remote learning. Many students did not attend virtual classes (Rolle, 2021). Teachers in the current study alluded to students' disengagement and lack of motivation regarding remote learning. It is important to find out what is needed to engage students in virtual learning and to gather their suggestions on improving the remote learning initiative. I suggest using polls to collect numerical data for quantitative analysis. Contacting students to collect interview data for qualitative exploration might be unfeasible and unwise.

A third possibility for future research is to explore the parent perspective on remote learning. Do parents know what their children are learning? Are parents able to assist their children in remote learning? What do parents need to improve the remote learning process for their children? A challenge though is how to contact parents. Perhaps the researcher can contact parents on social media, WhatsApp, or the school's web page.

Conclusion

In a qualitative study, I explored teachers' ICT integration into their virtual and blended classrooms in Bahamian public high schools during the COVID-19 pandemic.

The study revealed key findings related to the RQs. The key finding related to RQ1 is that the biology teachers based their decisions to use ICT on logical reasons and on their TK and PK. The key findings related to RQ2 are that local biology teachers experienced infrastructural/technical and pedagogical challenges integrating ICT into their classrooms but solved the challenges in several ways. The key finding related to RQ3 is that the ICT integration added value and teachers wanted to improve their ICT use to enhance teaching and student learning in remote classrooms. The teachers made several recommendations for improving the emergency remote education initiative. In a position paper (see Appendix A), I argue for education policymakers and stakeholders to adopt the teachers' recommendations.

The current COVID-19 pandemic accentuates the critical need to effectively integrate ICT to produce the best learning environments for today's classrooms and classrooms of the future. The emergency remote education plans adopted globally to provide students with undisrupted learning amid COVID-19 disruptions were not as successful as stakeholders would have liked (Kara, 2021; The World Bank, 2020a). Research on the development of sustainable education plans is needed (N. Johnson et al., 2020). Teachers in the current study recommend the provision of adequate digital devices and supportive infrastructure (P4; P8); training students on how to use ICT for learning (P2), relevant PD to improve teachers' PK and PK (P4; P7), support before and during virtual teaching and learning (P3; P4), and government–teacher collaborations (P8). Sustainable education plans may develop from collaboration between policymakers, teachers, parents, students and community partners working *at the same table* (P8).

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Appendix A: The Project

A Proactive Approach to Teaching Biology Remotely During COVID-19

A Position Paper

By

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Introduction

The onset of the COVID-19 pandemic forced unprecedented changes in education globally. For example, social distancing mandates to halt the spread of the pandemic dictated that students could no longer gather in large numbers in brick and mortar classrooms. Yet, education stakeholders still had an obligation to provide students with an education. Many countries, including the Bahamas, responded by selecting the *option* of an emergency remote education modality in place of traditional FTF instruction for students now confined to their homes (The World Bank, 2020a). Bozkurt et al. (2020) referred to emergency remote education as “surviving in a time of crisis with available resources” (p. 2). Few countries could offer a more established distance learning modality for all students quickly (The World Bank, 2020b).

On March 15, 2020, in compliance with COVID-19 health protocols, the then Prime Minister of the Commonwealth of the Bahamas announced the immediate suspension of FTF instruction, which was the predominant teaching and learning modality at the time (“Prime Minister’s Speech on COVID-19 in Full,” 2020). After “urgent planning and considerations”, the Minister of Education Science and Technology announced that schools on three major Bahamian islands would reopen on October 5, 2020 for students to learn remotely in a *virtual format* (Dunkley-Malc, 2020, Sept. 2). In preparation for the resumption of education in the new virtual modality, the Minister of Education, Science, and Technology assured the provision of needed accommodations such as digitization of the education system, professional development for teachers, and digital devices for all persons involved in the teaching and learning process (Dunkley-

Malc, 2020, Sept. 2). The Minister of Education also stated his awareness of the need for complete installation of the adequate level of internet service needed for connectivity to the department's virtual platform for thousands of students who would now remain at home in both the public and private education sectors (Dunkley-Malc, 2020, Sept. 2).

Brief Description of Study and Summary of Findings

In this current qualitative study entitled "Information and Communications Technology Integration in Bahamian Public High School Biology Classrooms," I explored teachers' information and communications technology (ICT) integration into the biology curriculum in their virtual classrooms during the COVID-19 pandemic. The criteria for participation selection was that the teachers taught biology in Bahamian public high schools and had integrated ICT into their FTF classrooms. The purpose of the study was to address the problem of teachers experiencing challenges integrating ICT into their FTF classrooms. However, because I collected data for my study during May and June 2021, my study became an exploration of the teachers' ICT integration into their virtual biology classrooms during the COVID-19 pandemic. Eight biology teachers from five Bahamian public high schools participated in the study, which was grounded in Mishra and Koehler's (2006) technological pedagogical and content knowledge (TPACK) framework. The framework highlights the importance of teachers having a combination of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK) to integrate technology into teaching effectively.

I developed three research questions (RQs) to address the problem and aligned them to the study's purpose. Firstly, how do local public high school teachers decide to use ICT in their classrooms to deliver the biology curriculum? Secondly, what challenges do local public high school biology teachers experience in their integration of ICT into their biology classrooms? Thirdly, what additional support, knowledge, or skills do teachers need to improve ICT use in their classrooms to positively impact student achievement in biology? Using interview questions aligned with the RQs, I collected qualitative data from virtually interviewing the participants on Zoom. I coded the data manually and digitally and examined the data closely for the emergence of themes and key findings. I applied the TPACK lens to the data analysis.

The key finding related to RQ1 was that the biology teachers in the five Bahamian public high schools based their decisions to use ICT on logistical reasons such as affordability and convenience of the ICT tools, their TK such as familiarity with the ICT tools, and PK such as how well the ICT tool helps in facilitating instruction and assessment of student learning. The key findings related to RQ2 were that local biology teachers experienced infrastructural/technical and pedagogical challenges integrating ICT into their classrooms and solved the challenges in several ways. The key finding related to RQ3 was that the ICT integration added value, and local biology teachers wanted to improve their ICT use to enhance teaching and student learning in remote classrooms. The teachers proposed several recommendations for improving instruction and students' learning in remote classrooms.

Purpose of the Position Paper

The purpose of developing the position paper was to inform local education policymakers and other education stakeholders about needed modifications to better support teachers in delivering instruction remotely. In the position paper I present an account of the biology teachers' recommendations for improving remote teaching and learning and reveal their positions on the initiative. I referred to the biology teachers by pseudonyms—P1, P2…P8. I argue that the recommendations proposed by the local teachers are valid and supported by research in the field of virtual education. I share the stance of Bozkurt et al. (2020) in proffering that the interruption of education during the COVID-19 pandemic signifies the importance of openness in education and highlights issues for consideration. I also share the stance of Johnson et al. (2020), who recommended developing sustainable education plans that can withstand the challenges of the ongoing COVID-19 pandemic.

I propose a proactive approach to developing a sustainable educational plan for the Bahamas that includes the local teachers' recommendations for providing the best teaching and learning environment during the COVID-19 pandemic and beyond. Giving credence to the recommendations forwarded by the local teachers from their experiences instructing and assessing students in a new virtual learning environment can contribute to the development of that sustainable education plan.

Recommendations

In the following sections, I discuss the recommendations from the teachers and the literature. Recommendations from the literature are based mostly on research about remote teaching and learning at the tertiary education level. Few studies relating to remote teaching and learning for K-12 classrooms were found. However, there appears a frantic rush to accomplish research in the field of remote teaching and learning at all educational levels, and new research is being published to libraries and websites daily.

My study presents a unique perspective because my literature search revealed no studies on remote teaching and learning during the COVID-19 pandemic at any educational level in the Bahamian setting. My study presents *new findings for the Bahamian context.* I present the recommendations from my study, and from the broader literature, in a non-judgmental way but with optimism for their implementation.

Access to Adequate Digital Devices and Supportive Infrastructure

Access to adequate digital devices and supportive infrastructure was important to the teachers in the current study. The teachers shared that based on TK and PK, they used ICT tools such as PPT's and virtual labs, and virtual teaching platforms such as Microsoft Teams and Google Classroom. Teachers in Gerencer and Hayes' (2020) study on remote learning best practices for teachers used mainly Google Classroom, Microsoft Teams, Screencast-O-Matic, Pear Deck, and Blackboard LMS in their virtual classrooms.

Some teachers in the current study mentioned that due to issues of affordability they were limited to selecting free ICT tools and that these frequently involved built-in restrictions. Teachers in the current study shared the challenges of using ICT tools while experiencing infrastructural issues such as inconsistent internet and electricity. Teachers reported that the MOEST's LMS did not work well. Teachers also shared that they could not access all students because some students had no digital devices or no supportive infrastructure at home. P8 shared that even though internet service was available at school, it was not fully accessible. The teacher stated,

> And I find that the MOEST put a lot of blocks on it. And I understand why. They blocked a lot of the social media apps to discourage students from getting distracted. But, they underestimated how much teachers actually use these same apps in their classrooms to keep the students focused.

Teachers in the current study proposed several recommendations to mitigate the challenges related to the accessibility of digital devices and supportive infrastructure. Recommendations include increased government funding to provide access to digital tools that teachers cannot afford out-of-pocket. Effendi-Hasibuan et al. (2019) made a similar recommendation.

The current study's participants also recommend the provision of digital devices and supportive infrastructure for all students. The teachers acknowledged the efforts of the MOEST and private partners to provide digital devices for students, but noted that despite these efforts, some students still did not have digital devices nor supportive infrastructure for using the devices. However, teachers reported that some students who had digital devices did not log on or turn in assignments to the remote learning platform. The Director of Education stated that 30% of students did not show up for online learning (Scott, 2021). Anecdotally, the percentage is estimated to be higher. The Bahamas' recently-appointed Minister of Education in the renamed Ministry of Education and Technical and Vocational Training (MOETVT) stated that her ministry "must get a data-driven evidence-based understanding of the implications of the pandemic and the disruption it has caused" (Rolle, 2021). She further stated that collecting the data "is critical so that we may swiftly implement strategically-targeted remedial interventions to reverse or minimize the damage caused by the disruption of education" (Rolle, 2021).

Regarding students' absenteeism from virtual classrooms, P2 opined "because they're at home, students may have felt that they're on vacation." From their studies, Al Ghazali (2020) and Gerencer and Hayes (2020) also cited a lack of students' willingness and motivation to learn on virtual platforms. Teachers in the current study stated that they addressed students' non-participation by providing student-friendly virtual classrooms. Teachers called the delinquent students and encouraged participation by repeatedly opening assignments. Gerencer and Hayes (2020) and Koehler and Farmer (2020) also recommended the establishment of student-friendly virtual platforms by communicating clear expectations for students about course load, course formats and deadlines.

Teachers in the current study recommend investigating other issues such as psychosocial factors that can affect students' learning on virtual platforms. Miller (2021) and Withers et al. (2021) forwarded a similar recommendation. Teachers in the current study recommend research on parental involvement in their children's virtual learning. Bozkurt et al. (2020), McCarthy and Wolfe (2020), and Williamson et al. (2021) proffered the importance of parents assisting their children and encouraging them to learn in virtual classrooms. Further, Gerencer and Hayes (2020) and Koehler and Farmer (2020) recommend that teachers communicate virtually with parents to help to build an effective learning community of teachers, parents, and students.

Professional Development/Training for Remote Teaching

The COVID-19 pandemic highlighted the need for educators to become familiar with and trained in online pedagogies. Bozkurt et al. (2020) cautioned that online teaching is not simply presenting FTF pedagogies in digital format. P8 acknowledged this when she said “something that worked in person may not work virtually.” Sumer et al. (2021) recommended that teachers learn the pedagogical differences between FTF and online teaching to prevent them transferring their FTF classroom habits to distance learning systems. Teachers in current study shared that they leveraged their TK, PK, and CK to helping students succeed on the new learning platforms. P5 stated “constant trial and error helped us understand what enhanced the lessons and student learning.” However, this might not have been the best approach. Magana (2017) and Maharaj-Sharma et al. (2017) recommend the development of clear guidelines for selecting and using ICT for instruction and assessment.

Participants in the current study had previous experience using ICT in FTF classrooms. However, in the COVID-19 pandemic, the teachers needed to acquire new TK and adopt new pedagogical practices for remote teaching. Literature research confirmed that even teachers experienced in using educational technologies to support student learning in classroom environments can struggle when operating in a wholly online environment (The World Bank 2020b). Interview data revealed that some teachers in the current study had challenges selecting appropriate ICT tools for instruction and understanding how to assess students online. P7 stated, “we are teacher-trained but not technology-trained.” Mishra and Koehler (2006) proffered that the interweaving of technology training into training on content and sound pedagogies is the foundation of effective teaching with technology.

Because of their challenges integrating ICT into their classrooms, teachers in the current study recommend that education leaders provide PD/training to boost teachers' TK and PK and improve their remote teaching. The recommendation echoes in the existing literature. Al Ghazali (2020), Nasr (2020), Serdyukov (2017), and Sumer et al. (2021) recommended technology training to equip teachers to integrate ICT into remotely-delivered curricula effectively. Ervin-Kassab (2020) shared an example of how participating in a "Sandbox" or "Playdate" learning space helped teachers become familiar with technology and connect practice to theory. According to Ervin-Kassab, what worked was having short, TPACK-structured video content to support learning and faculty involvement in using learning management platforms. Bozkurt et al. (2020) posited that unless teachers possess the technological competence to use the tools effectively, investing in technologies such as broadband internet, computers, and mobile technologies would not create success stories.

P6 from the current research remarked that not all teachers in the school were willing to add the new teaching modality to their teaching skills. "They find that it's learning something new. They don't want to add this to their method of teaching" (P6). Nenko et al. (2020) confirmed faculty unpreparedness, negative attitude, and low motivation to adopt remote technologies as challenging for implementing online instruction. However, learning opportunities such as the 'sandbox' initiative reported by Ervin-Kassab (2020) could be a way to ease the transition to remote teaching for educators who might be technophobic, have a fear of innovation, or have weak technology skills.

The teachers in my study recommend making PD relevant to the biology subject area. The teachers opined that the workshops provided by the MOEST or by their schools were usually of a general nature and sometimes did not apply to the science content area. As P8, who suggested the creation of a virtual space for biology teachers said "if we can have just a forum where we just share all of that, different tools that we used, how we implemented it in different topics, I think that alone can be the basic structure of how we can now move to this digital curriculum."

Teachers in the current study also recommend the provision of on-time, on-site technical support to troubleshoot technical problems. The teachers recommend training for students too on how to use technology for learning. As P5 commented "I found that while we say this generation is tech-savvy, they were not tech-savvy in using it for school." Teachers in the study noted that they had to use limited instructional time to teach netiquette to their students and how to navigate the remote learning platforms before even attempting to deliver biology content to the students. Teachers reported that having to do this presented challenges for completing the biology syllabus.

Alternative Pedagogies and Assessment Techniques

Teachers became students in online classrooms (Nasr, 2020). Teachers in the current study stated that they learned how to adapt their instruction and assessment methodologies for the new remote learning modality. All of the teachers in the current shared that they modified their instructional practices for remote teaching. For example, they added more activities to their lessons, created interactive lessons to engage their students, and used new digital software for delivering content.

Teachers in the current study reported challenges with assessing students in a virtual environment but offered no recommendations to mitigate the challenges. However, researchers in the field of virtual learning proffer some recommendations. For example, Hamilton (2018) recommended alternative ways for formative and summative assessment of students' learning online. Alternative assessment strategies included creating projects, conducting research, accessing interactive websites, building a web presence, producing videos, and interacting with persons around the globe (Hamilton, 2018). Gonzalez (2020) recommended giving students "wings" of voice and choice, for example, by replacing summative exams with project-based learning evaluation.

Most of all, teachers in the local study struggled with teaching scientific skills remotely and assessing students' skills achievement. Traditionally, students learned scientific skills, such as suggesting hypotheses, designing and conducting experiments to test their hypotheses, collecting and analyzing data to get results, and evaluating the results to make inferences by conducting hands-on experiments in physical laboratories (Tsichouridis et al., 2019). However, the onset of remote learning at the start of the COVID-19 pandemic meant that science laboratories in brick and mortar schools were no longer accessible to students (Chandrasekaran, 2020; Kapici et al., 2020; Tsichouridis et al., 2019). Recommendations from the literature included balancing virtual activities with hands-on activities students perform at home (Chandrasekaran, 2020; Wright, 2020) and using virtual labs (Chandrasekaran, 2020; Guzmán & Joseph, 2021). However, as P2 from the local study stated "we weren't able to do coursework (hands-on laboratory activities) because we needed them to be in the lab."

Six of the eight teachers in the local study reported that they tried virtual labs to teach coursework. The six teachers reported that as a failure. Four of the teachers explained that they could not afford to pay for virtual labs. Moreover, the teachers reported that sometimes they could not find suitable experiments for teaching the different skill levels required by the syllabus and that assessing the students' skill levels within the virtual labs was difficult. The MOEST offered teachers the option of having their students take the Paper 5 alternative to coursework for the Bahamas General Certificate of Secondary Examination (BGCSE) in biology, but this intervention also did not appear to work. P8 explained that the aim of Paper 5 is to "walk students through how a lab should look," but shared that the students found it difficult to *visualize* a lab and that they viewed Paper 5 as "just another paper to write" for the BGCSE.

What then are the possible solutions? I propose one here, the only place in this position paper where I make a recommendation. The recommendation derives from my former roles as a biology teacher in Bahamian public high schools and my many years as the chief marker responsible for vetting all coursework scores in biology in the national high school examination. I recommend creating a *virtual laboratory resource* for the biology teachers with examples of activities that balance hands-on and virtual science activities and include criteria for teachers to assess the students' work. I recommend that the MOETVT select a team comprised of teachers with coursework expertise and technology-competent staff from the ministry to create the virtual laboratory guide/resource. The resource can be used in PD workshops or accessed by teachers as needed. I have provided an example of a virtual laboratory activity that conforms to the criteria for a skill level for the coursework component of the biology curriculum. The laboratory activity includes criteria for assessing the students' work (see Appendix B).

No one can predict how long the COVID-19 pandemic will last or exactly how classrooms of the future will look. If the COVID-19 pandemic persists, I can visualize a scenario where students in virtual biology classrooms have never seen laboratory apparatus such as a test tube or beaker and cannot explain how a thermometer or Bunsen burner works. It might be necessary eventually to remove the coursework component from the biology curriculum and have students learn biology purely theoretically. I also recommend that the MOETVT decides whether students continue to submit paper files of their coursework or upload them in a digital format. I suggest that students upload biology coursework digitally until instruction returns to a FTF modality. In the meantime, the teaching of the coursework component remains a requirement of the biology curriculum. My recommendation to develop an online laboratory resource offers a strategy for teachers to accomplish coursework in the current remote learning classrooms. I offer my services in helping to create the online resource or in any other capacity that helps to implement the position paper.

Amendments to the Curriculum and National Examinations

P5 and P8 in my study recommend changes in the biology curriculum to improve its delivery on remote teaching and learning platforms. The recommendations include adding more local content to the curriculum and shortening the syllabus. Some of the participants referred to the length of the biology curriculum, and to the difficulties of completing the lengthy syllabus in a remote teaching modality. P8 stated, “the ministry needs to now look at ways to pull out topics that are not necessarily needed in biology so that we can incorporate more technology.” Al Ghazali (2020) also recommended that educational authorities improve educational content and adapt syllabi and assessment techniques within the limitations imposed by COVID-19 restrictions. Further, Al Ghazali recommended that educational authorities offer flexibility to teachers to carry out the necessary modifications in the taught materials and assessment techniques. P8 in my study mentioned about changing the format of the national BGCSE examinations to a digital one. Presently students are learning with digital devices and technologies but are required to go to their schools to write a pen and paper exam.

Another recommendation from the local study is that students operate on a timetable specific to the virtual classroom and not just with a FTF one transferred to a digital platform. P4 stated “instead of five periods, perhaps they could have had three, that way they would have ample time for a break in between each period.” The teacher reported students’ fatigue from being constantly “on” from 9 a.m. to 3 p.m.

Empathic Support

In the field of education, support normally refers to the implementation of educational strategies, curriculum adaptations, and continuing educational provisions to improve learning (Alemdag et al., 2020; Mishra et al., 2019). However, the COVID-19 pandemic added new considerations to the term “educational support.” For example, Williamson et al. (2021) posited that the remote instructional modality has highlighted the need to provide emotional support for teachers, students, and parents. Bozkurt et al. (2020) stated “parents are overburdened between regular daily/professional duties and emerging educational roles, and all parties are experiencing trauma, psychological pressure and anxiety to various degrees, which necessitates a pedagogy of care, and empathy” (p.1).

The most valuable resource reported by some of the teachers in my study for coping with emergency remote instruction was their collaboration and teamwork with other teachers (P2, P3, P4, P5). Teacher peer support groups built for example through texting, WhatsApp, WeChat, and Facebook, can provide invaluable mechanisms for informal support and official information-sharing (Harland, 2020; The World Bank, 2020b). Harland (2020) reiterated the important role professional networking could play in providing insight on creating balance between physicality and technology in future classrooms. Regarding teacher-teacher peer support, P4 stated,

> It helped me as a teacher because we were team-teaching and I could see other teachers’ teaching styles, and the things that they would do and how they would teach different topics. That helped me because now I can better deliver to my students by using some of those techniques that were used.

However, the teachers in the current local study also wanted empathic support *from their government*. Teachers wanted to “feel” the presence of the MOEST in schools. To illustrate this point, I refer to the devices teachers received from the MOEST to facilitate remote instruction to students. P2, P3, P7, and P8 reported that the tablets were inadequate, due to insufficient storage capacity and difficulty accessing the LMS.

Teachers said that they “put aside” the tablets, and used their own digital devices. P8 stated that she used the tablet “as a desk weight.” But teachers reported that no one from the MOEST checked whether the tablets were adequate to facilitate remote instruction. As P4 said, the MOEST needs to “provide continued support, and the checking in to see if what they say they have given to us is working, like the devices, etc.” P4 elaborated “just to make sure that what you put in place is effectively helping those you said it should be helping. And collect it back if necessary.” A possible way to check in with teachers is for MOETVT personnel to visit schools periodically to talk with teachers, or alternatively they can conduct email surveys among the teachers – easily done because all teachers have an email address assigned by the MOEST/MOETVT.

P3 recommended that school administrators’ frequent professional assessment of teachers focus on offering help to improve the remote teaching experience and relieve teachers’ stress rather than finding fault with what teachers are doing in their virtual classrooms. The teacher opined that many school leaders have an inadequate understanding of the ways teachers are using ICT, have little knowledge about evaluating teachers in the remote learning modality, and continue to evaluate teachers on old FTF classroom criteria. Johnson et al. (2020) investigated the experiences of faculty and administrators transitioning to emergency remote teaching at 672 post-secondary U.S institutions. In that study, administrators identified needs including remote education training for institutional leaders, one-on-one consultations with online learning experts, and information on how to support teachers and students working from home.

It also appears that students need empathic support as they learn remotely. P1, P3, and P8 from the current study noted that many students struggled to complete assignments and learn content on the remote platforms. Kara (2021) noted that the rapid transition to online platforms was made on the assumption that all students had a favorable environment for studying at home. P3 and P4 noted the inaccuracy of the assumption. Canipe and Bayford (2020), Nasr (2020), and Withers et al. (2021) recommended that teachers demonstrate flexibility with their online students, such as relaxing deadlines or excusing instances of non-participation in synchronous classes when students might be studying in less-than-ideal learning environments at home.

Parents also need support to scaffold their children's remote learning. McCarthy and Wolfe (2020) recommended that education leaders continuously evaluate the online learning plan to evaluate the effectiveness of strategies. This can be done by asking specific questions to gauge parent and student engagement and satisfaction, and by offering frequent opportunities for parents, teachers, and students to suggest improvements (McCarthy & Wolfe, 2020). Education systems should consider reaching out to parents and caregivers explaining expectations for their children learning online, offering suggestions on how parents can support their children, and providing resources such as websites, online help desks, and call centers where possible (The World Bank, 2020b). This is a recommendation the MOETVT might consider.

A Unified Information and Communications Technology Policy/Plan

Williamson et al., (2021) opined that there is a great need during the COVID-19 pandemic to carefully analyze decisions about educational technology practices and policies. Teachers in the current local study want more input into the decisions being made for teaching and learning on remote platforms. The teachers recommend the creation of a unified government–teacher ICT policy/plan that includes input from their experiences in their remote classrooms. As P8 from my study stated,

> A lot of decisions are being made in terms of education behind closed doors and the teachers – the ones who are forced to carry out these changes are not involved on these conversations. So, I believe they should give us an open table. If they're making decisions, if they're thinking of ways to revamp the system, they should open that up where the teachers can listen in and still give feedback of what they suggest. You don't have to put every suggestion into place but at least be willing to hear what we have to say.

P3 iterated teachers' willingness to share their experiences with remote teaching during the COVID-19 pandemic. The teacher recommends that the government access the information from teachers and incorporate it into improving ICT integration into future biology classrooms. Fletcher and Nicholas (2018) stated that if teachers possess the motivation to integrate digital technology into teaching and learning, they need the support of the education system at local and national levels. Zagami et al. (2018) recommended that policymakers engage with local stakeholders, including industry, regional and district managers, principals, teachers, parents, and community representatives, to discuss required policies, the framing of goals, and implementation strategies for local conditions and circumstances.

Teachers' Positions on Remote Teaching and Learning in COVID-19

The current study's data revealed that the teachers believe that the remote teaching and learning initiative added value, especially for their professional development. Seven of the eight teachers reported an improvement in their TK. Teachers also shared that they gained PK about how to implement new teaching methodologies in remote teaching platforms. Some teachers shared about valuable teacher-teacher collaborations that developed from teaching remotely. For example, teachers in School B selected ICT tools and created content and assessments jointly. Additionally, the teachers from the cited school applied team-teaching techniques to manage large numbers of students in virtual classes. P3 from the school shared "I learned to appreciate working with my colleagues. I'm able to see their strength, and how we work together. So, that's a plus from this whole integration."

However, the current study's participants gave mixed views about the values added for students from the remote teaching and learning initiative. P3 stated "students were able to get the best of each teacher based on the content, and that is something we should not give up." Most teachers were undecided about the improvement to student learning. P4 stated clearly "I don't think it was effective. There were a lot of things that need to be corrected or changed a little bit to incorporate the new dynamics." P7 opined that students initially gained from learning remotely but overall did not benefit. Yet another teacher, (P8), stated that her students had difficulties understanding the taught information online, and wanted to return to FTF learning. However, teachers did not proffer many solutions for improving learning outcomes for students from the remote teaching intervention. Indeed, research indicated that virtual learning was of limited value for most students, especially those in poor communities who are subject to numerous disadvantages (The World Bank, 2020b).

Further research on the factors that influence student learning in virtual classrooms and the impact of the remote teaching initiative on learning outcomes is needed. Researching parental involvement in the success of their child's remote learning is another area for future research, as teachers do not constitute the only factor in student success (Al Ghazali, 2020; Miller, 2021; Withers et al., 2021). Finally, although emergency remote learning enabled the continuation of education during the COVID-19 pandemic, it does not appear to be a long-term solution (Johnson et al., 2020; The World Bank, 2020b). Research on the development of sustainable education plans is needed (Johnson et al., 2020).

Conclusion

In conclusion, I restate my argument that the recommendations proposed by the local teachers for improving remote teaching and learning are valid and supported by research in the field. Though small, my study can provide insights that may apply to other locations. My study's findings can inform local educational policymakers and other education stakeholders about needed modifications that can better support teachers in delivering remote instruction effectively.

Based on recommendations from the local teachers and the literature, the action plan is to initiate immediate amendments to the Bahamian governments' policy/plan for remote education during the COVID-19 pandemic. Input from the biology teachers' experiences with implementing the initiative since 2020 is essential. The teachers in the current local study propose collaboration between themselves and the Ministry of Education to review existing educational policies/plans. The teachers want to see openness in education through joint decision-making. Suggested areas for reexamination include equitable access to adequate devices for teachers and students, infrastructural, technical, and empathic support, relevant PD/training, and new pedagogies and assessment strategies for creating an effective virtual learning environment.

Data from the current local study indicated that emergency remote instruction implemented in response to the COVID-19 pandemic might not have been the best solution for educating students during the pandemic. The Director of Education in the Bahamas cited that 30% of students were not showing up for online learning (Scott, 2021). This translates to about 15,000 of approximately 50,000 K-12 students in the Bahamas, and is concerning, untenable, and unsustainable. But it is a new day, with new possibilities for education arenas. There is an urgent need to chart a sustainable education pathway for the duration of the COVID-19 pandemic and beyond.

Recommendations forwarded by the local biology teachers and gleaned from existing literature in the virtual learning field need to be considered. For example, examining teachers' classroom practices, offering professional development opportunities, partnering with community and other private organizations, and conversing around the *same table* with policymakers, school administrators, teachers, parents, and students can add value to educational offerings. A sustainable education pathway may thus be forged proactively, collaboratively and deliberately.

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Appendix B: Sample of Virtual Biology Experiment

Title of Activity: Investigating Global Coastal Cleanup
Skill Level C: Handling Experimental Observations and Data

Introduction:
The students will manipulate data from a 2020 International Coastal Cleanup activity. The activity is related to the syllabus module of "Pollution."

Students can access the data on the link: https://oceanconservancy.org/trash-free-seas/international-coastal-cleanup/annual-data-release/

Or teachers can give the students the data in a table:

Top 10 Items Collected	Pounds of Trash (rounded off)
Cigarette butts	965,000
Beverage bottles (plastic)	627,000
Grocery bags (plastic)	272,000
Food wrappers (candy, chips, etc.)	574,000
Take out containers (plastic)	222,000
Straws, Stirrers (plastic)	224,000
Bottle caps (plastic)	410,000
Beverage cans	163,000
Beverage bottles (glass)	146,000
Other trash	519,000

Instructions for Students:
1. Calculate the total amount of trash collected. Show working.
2. Calculate the total amount of plastic trash collected. Show working.
3. Write a conclusion based on evidence from the data and on you knowledge about pollution. The conclusion can include: identifying the types of trash; highest category of trash; decomposition rates; trash that suggests an unhealthy lifestyle.
4. Identify possible sources of error in the collection of the data.
5. Upload your work into the LMS. Save your work to submit for external evaluation.

Follow-up Activity - Students research the benefits of cleaning up our beaches.

<u>Assessment of Student Work</u>

The following skill levels are based on the "Guide to Coursework" criteria

Level	Criteria
2	Accurate calculations; obvious/basic conclusion
4	Accurate calculations; relevant conclusion
6	Accurate calculations detailed relevant conclusion; suggests sources of error in data collection
1,3,6	For students who do not quite meet the criteria for levels 2, 4, and 6.

Appendix C: Permission to Reproduce Published Work

Re: Permission Request

Chandrasekaran, Arun Richard <arun@albany.edu>
Fri 10/8/2021 5:35 PM
To: Cynthia Johnson

Figure_revised.tif
2 MB

Hi Cynthia,

Sure, feel free to use that figure in your paper. Attached is a high-resolution image if you need one.

Best,
Arun

Appendix D: Interview Questions

1. What are some ICT tools that you use in your biology classroom?
2. What are some reasons for integrating those ICT tools into your biology classroom?
3. What factors did you consider in selecting those tools?
4. What are some of the challenges you experience with integrating ICT into the biology curriculum?
5. What modifications to ICT implementation have you made or anticipate making during your virtual teaching?
6. What kind of support, knowledge, or skills do you believe you need to improve your ICT use in your biology classroom?
7. What can your school’s administration do to assist you in integrating ICT effectively into the biology curriculum?
8. What can the government do to help you in integrating ICT effectively into your biology classroom?