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Postgraduate Science Students' Impressions and Experiences of Online Pedagogical Practices: Implications for Technology-Enhanced Pedagogy

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Abstract. This study explores the postgraduate science teachers' conceptions and experiences of online pedagogical practices in diverse school contexts. Embracing technology-enhanced pedagogy remains a key strategic imperative within the context of evolving pedagogical benefits associated with the advent of the Fourth Industrial Revolution (4IR). As key agents of educational change, science teachers face the key imperative to harness the pedagogical affordances of online platforms with a view to realizing the achievement of envisaged educational outcomes. Furthermore, research studies on online teaching have predominantly focused on technological aspects and very little on their impact on humans. The empirical investigation adopted a qualitative case study design and involved 20 purposively selected postgraduate science students from diverse school contexts in South Africa. Data were collected through the administration of an open-ended survey questionnaire and semi-structured interviews. Key findings emanating from the empirical investigation indicated that postgraduate science teachers' coherent adoption of appropriate online pedagogical strategies was largely hampered by a lack of technological resources and inadequate professional capacity to implement online teaching and learning in diverse school contexts. Sustainable teacher professional development opportunities on the utilization of virtual digital platforms ought to be provided with a view to enabling postgraduate science teachers to harness the pedagogical affordances of online teaching and learning.

Keywords: pedagogical practices; science teacher conceptions; science teacher experiences; technology-enhanced pedagogy

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1. Introduction

This paper examines postgraduate science students' conceptions and experiences of online pedagogical practices in diverse school contexts. These postgraduate science students were in-service teachers practising in various schools in South Africa. The COVID-19 pandemic challenged teachers to rethink and reimagine their pedagogical practices with a view to harnessing the pedagogical affordances of remote teaching and learning. In essence, the COVID-19 pandemic provided opportunities for teachers to embrace digital transformation. In response to the key imperatives of digital transformation, science teachers adopted innovative pedagogical practices to maximize the pedagogic benefits that accrue from the meaningful implementation of remote teaching and learning (Kaur & Bhatt, 2020). However, existing socio-economic disparities within the South African basic education system stifled a meaningful transition from face-to-face to remote teaching and learning. Studies conducted in the United Kingdom, the United States, and Germany revealed that the transition from face-to-face to online teaching and learning was largely seamless in well-resourced schools (e.g., Adams-Prassl *et al*., 2020; Mitchell, 2020; Turnbull et al., 2021). This transition was essentially predicated on the assumption that teachers and learners have adequate access to bandwidth (Lederman, 2020).

There is a need for critical interrogation of science teachers' conceptions and experiences of online pedagogical practices in view of their implications for technology-enhanced pedagogy. The advent of the 4IR provides opportunities to harness pedagogical affordances of technology-enhanced learning to foster pedagogic innovation in science classrooms through the use of interactive game-based applications such as Kahoot. In this sense, this article makes a significant intellectual contribution toward coherent realization of this key strategic imperative. Fostering pedagogic innovation in science classrooms is commensurate with the quest for the meaningful development of scientific literacy through the coordinated enhancement of the quality of science education in its broadest sense. As such, this study explored the postgraduate science teachers' conceptions and experiences of online pedagogical practices in diverse school contexts.

2. Literature Review

The COVID-19 pandemic posed formidable challenges to the provision of instruction in South African schools. The transition to online teaching and learning had varied implications for technology-enhanced pedagogy in diverse school contexts. Science teachers faced the key imperative to migrate to online and blended teaching modes. There is a need to interrogate critically the implications of pedagogical practices adopted during online teaching (Kirkwood & Price, 2014; Salmon, 2014). Critical interrogation of the implications of online teaching mode to pedagogy requires reflection on science teachers' conceptions and experiences of online pedagogical practices. Gillett-Swan (2017) argues that while pedagogical practices applicable to face-to-face contact modes can utilized in online learning environments, they cannot merely be the application of a "one-size-fits-all approach". In fact, Orlando and Attard (2015) state that "teaching with technology is not a one-size-fits-all approach as it depends on the types of technology in use at the time and also the curriculum content being taught" (p. 119). While science

teachers endeavour to provide equitable learning experiences for all learners in online learning environments, the realization of this pedagogic goal may be hampered by a lack of access to technology and the fact that teachers may feel ill-prepared to teach online as they may still be learning to use online platforms (Rucker & Downey, 2016).

South African schools are classified as public and private schools. A considerable number of public schools are largely under-resourced as compared to private schools (Amnesty International, 2020). Nevertheless, technology-enhanced pedagogy requires the availability of adequate ICT infrastructural resources. In addition, school science is by its very nature a practical subject. Online learning environments ought to make provision for opportunities for the performance of practical work. The key conundrum that arises revolves around the extent to which science teachers create opportunities for the performance of practical work through the adoption of appropriate online pedagogical practices. Online teaching may be synchronous or asynchronous depending on the requirements of online environments, notwithstanding the fact that online environments provide opportunities for the delivery of instruction (Williams et al., 2012). These practical considerations underscore the need for a critical reflection on in-service science teachers' conceptions and experiences of online pedagogical practices when teaching science. Thus, the article grapples with two key questions, namely (a) How do science teachers conceptualize online pedagogical practices when teaching science in online learning environments? (b) What were science teachers' experiences of online teaching and learning during the COVID-19 pandemic?

3. Conceptual and theoretical framework

The empirical investigation reported in this article is framed by the Advanced Signal (AS)-TPACK as the underlying conceptual framework. As proposed by Mpungose (2018), the key elements of the AS-TPACK framework are content knowledge signals (subject themes), pedagogical knowledge signals (rationale, goals assessment, role, accessibility, time, environment, activities), and technological knowledge signals (hardware resources, software resources, ideological-ware resources). It is important to point out that the framework's structural configuration is anchored on the subject matter (content), teaching methods (pedagogy), and resources (technology) in a pedagogic sense. Mishra and Koehler (2006) posit that the acquisition of the envisaged teacher knowledge hinges to a large degree on subject matter competence, pedagogical skills, and the proficient use of technology. According to Verloop *et al.* (2001), teacher knowledge refers to understandings which are relevant to teachers' daily practices, while pedagogical knowledge is central to the development of requisite skills in any instructional setting. In an attempt to demystify the nature of pedagogical knowledge, Khoza (2019) asserts that pedagogical knowledge involves teaching and learning driven by goals such as aims, objectives, and learning outcomes.

Pedagogy is described by Moyles et al. (2002) as "an extremely complex phenomenon comprising a wide variety of practices underpinned by principles acquired through training and as a result of professional experiences and personal understandings" (p.1). Pedagogical practices are teacher actions that facilitate and promote learning. Empirical exploration of science teachers' online pedagogical practices is intrinsically linked to the utilization of educational technology.

Govender and Khoza (2017) maintain that educational technology involves "the effective use of technological tools (resources) in teaching and learning" (p.67). Mpungose (2018) argues that having content, technological, and pedagogical knowledge without reflecting specifically on signals within each knowledge component may potentially render teaching and learning of Natural Sciences, Physical Sciences and Life Sciences in particular a fruitless pedagogic undertaking.

The empirical exploration as encapsulated in this article is predicated on the provision of a critical reflection on postgraduate science teachers' conceptions in relation to technology-enhanced pedagogy. González (2010) classifies teachers' conceptions of e-learning into four qualitatively different categories: (a) provision of information to students; (b) occasional communication among unit participants; (c) engaging students in online discussions; and (d) supporting knowledge-building tasks. While technology-enhanced learning involves the application of technology to teaching and learning, however, it does not appropriately address the complexity of the partnership between education and technology (Bayne, 2014). As a consequence of the prevalence of the COVID-19 pandemic, postgraduate science teachers were compelled to deliver instruction using online platforms in the face of prevailing technical challenges and often without proper technical support (Hodges *et al*., 2020), particularly in developing countries such as South Africa.

The other fundamental pedagogic challenge facing science teachers within the broader South African context is the lack of adequate pedagogical content knowledge (PCK) (Shulman, 1987) which is essential for online teaching and learning (Ching et al., 2018). By its very nature, online teaching requires sound pedagogical content knowledge related to the design and organization of meaningful learning experiences through the creation of distinctive learning environments with the help of digital technologies. It is argued in this article that the AS-TPACK framework should make provision for pedagogical practices, teacher conceptions, teacher experiences, and technology-enhanced pedagogy as key constructs explored in this empirical investigation. More specifically, the key elements of the AS-TPACK framework can make provision for the constructs under exploration as follows: content knowledge signals (Natural Sciences, Physical Sciences, and Life Sciences), pedagogical knowledge signals (online pedagogical practices, teacher conceptions, teacher experiences), and technological knowledge signals (technology-enhanced pedagogy and its inherent ramifications).

The empirical exploration is underpinned by the multimodal model for online education proposed by Picciano (2017) as the underlying theoretical framework. As a theoretical lens, the framework is anchored on a learning community whose key components are content, social/emotional aspects, self-paced/independent study, dialectic/questioning, evaluation/assessment, collaboration/student-generated content/peer review, and reflection. As key participants in the empirical exploration, postgraduate science teachers constitute a learning community by virtue of their pursuit of a common goal to realize online teaching and learning. The framework is relevant to the inquiry as the components can serve as key ingredients required for the delivery of online teaching and learning.

While AS-TPACK provides insights into science teachers' content, and technological, and pedagogical knowledge, the components of the multimodal model for online education inform the establishment of communities of practice.

4. Methods

The research design, selection of participants, data collection and analysis procedures are discussed below. Ethical considerations are also presented.

4.1 Research design

The empirical investigation adopted a qualitative study design (Creswell, 2014). Qualitative study helps in the exploration of a phenomenon within a particular context through various data sources and provides opportunities to undertake the exploration through a variety of lenses to reveal multiple facets of the context (Baxter & Jack, 2008). Therefore, the unit of analysis is science teachers who were engaged in postgraduate studies at a South African higher education institution.

4.2 Participants and sampling procedure

Purposive sampling techniques (Etikan et al., 2016) were employed to select the target participants from a given population of 53 postgraduate science teachers from diverse schools in a South African university. The following criteria were used to select the target participants from a population of 53 postgraduate science students (B.Ed. Honours, M.Ed. and Ph.D.): diversity of the schools in terms of socioeconomic profiles and learners' sociocultural backgrounds, teaching experience, academic understanding of the need to teach for understanding, willingness to participate, and exposure to the use of learning technologies. Through the use of purposive sampling, a total of 20 participants were selected to participate in this study.

4.3 Data collection procedures

Qualitative data were collected through the administration of an open-ended survey questionnaire (Appendix 1) and semi-structured interviews. The questionnaire had three constructs: (a) Teachers' biographical profiles (seven items); (b) Postgraduate science teachers' conceptions about online pedagogical practices (five items); and (c) Postgraduate science teachers' experiences of online teaching and learning (five items). By their very nature, open-ended questions do not provide participants with a predetermined set of answer choices but instead allow participants to provide responses in their own words. The open-ended survey questionnaire was developed by the researchers and piloted with eight postgraduate students enrolled in an ICT online programme before administration with the participants. The open-ended survey questionnaire was piloted before the administration to the participants. The questionnaire items were then modified based on feedback obtained from the pilot phase. When analysing data, the two researchers coded the participants' responses, and 90% inter-rater kappa reliability was obtained.

Semi-structured interviews were conducted with four (4) postgraduate science teachers who were selected based on their knowledge and skills in implementing online pedagogical strategies. A semi-structured interview is a qualitative data-collection strategy in which the researcher asks respondents predetermined open-ended questions. The advantage of using a semi-structured interview is that it

allows for open-ended responses from participants for more in-depth information. The interviews enabled the researchers to probe participants' conceptions further and to provide elaboration on their questionnaire responses.

4.5 Ethical considerations

Permission to conduct research was granted by the Research Ethics Committee of the institution where the research was carried (Ethical Clearance: Sem-2020-031). Research procedures were explained to the participants and participation was voluntary. Pseudonyms were used to ensure anonymity and confidentiality. Furthermore, informed consent was obtained from the participants. In addition, participants were allowed to withdraw their participation at any stage without repercussions.

5. Findings

Key findings emanating from the study are clustered according to themes that emerged during data analysis, namely (a) mixed conceptions on online pedagogies; and (b) context-dependent experiences on online teaching and learning. As the context is important in this study, the participants' demographic profiles are provided in Table 1.

Table 1: Participants' demographic profiles

Characteristics	Category	n	Percentage
Gender	Female	15	75.0
	Male	5	25.0
Race	Black	18	90.0
	Coloured	1	5.0
	White	1	5.0
Age in years	Below 25	2	10.0
	25-30	9	45.0
	31-35	1	5.0
	36-40	3	15.0
	41+	5	25.0
Subject taught	Life Sciences	15	75.0
	Natural Sciences	11	55.0
	Physical Sciences	4	20.0
Type of school	Township	12	60.0
	Suburban	5	25.0
	Private	3	15.0
Tech. devices used	Smartphone	11	55.0
	Laptop	13	65.0
	Desktop	2	10.0
Source of connectivity	Data	9	45.0
	Wi-Fi	11	55.0
ICT skills	Very good	5	25.0
	Good	8	40.0
	Average	7	35.0

The majority of teachers (75%) were Black females (seven with a B.Ed. Honours, six with an M.Ed. and three with a Ph.D.) teaching in township schools. Township schools are under resourced as compared to suburban and private schools. In addition, township schools enrol a large proportion of learners from poor socioeconomic backgrounds. The majority (45%) of the participants fell within the 25-30 years age range. These postgraduate science teachers are expected to be technologically savvy and capable of teaching using learning technologies in online learning environments. Table 1 also shows that the teachers taught several science subjects such as Life Sciences, Physical Sciences, and Natural Sciences. Some of the postgraduate science teachers had access to technological devices such as smartphones and laptops which enabled them to choose the most suitable device to use depending on the type of online task at hand. Postgraduate science teachers used their own data or Wi-Fi for Internet connectivity when using online platforms. However, high data costs remained a major impediment for the teachers. A total of 35% of the teachers indicated that their technical knowledge and skills were inadequate; this challenge had implications for the choice of pedagogical tools and strategies they employed when using online platforms.

The following themes were generated from open-ended questionnaire items and semi-structured interviews.

Theme 1: Mixed conceptions on online pedagogies

Postgraduate science teachers viewed online teaching as an important development that motivated them to rethink how they taught and implemented pedagogical approaches. They implemented pedagogical approaches in response to the key requirements of pedagogic innovation and digital transformation. The postgraduate science teachers embraced the use of technological devices for online teaching as being technology savvy. On the other hand, teachers with inadequate technological skills and who lacked appropriate digital devices viewed online teaching as a challenging task imposed on them by the prevailing circumstances.

The postgraduate science teachers expressed fundamental appreciation of exposure to the utilization of virtual digital platforms (e.g. Microsoft Teams, Zoom, Google Meet). However, they bemoaned the lack of professional capacity to use technology effectively. Postgraduate science teachers who had received prior professional training in their schools indicated that they still encounter challenges when it comes to the identification and utilization of appropriate technological tools in online learning environments. These challenges can be attributed to the inadequacy of the training they received. During the interview, one of the teachers acknowledged, "Online teaching was not very effective for me and my learners as I lacked the necessary technical knowledge and skills."

Some of the postgraduate science teachers indicated that they found it increasingly challenging to provide meaningful opportunities for practical work (e.g. simulations, use of videos, voice-over demonstrations) in online learning environments. More specifically, postgraduate science teachers found it extremely difficult to engage learners in inquiry-based learning as they lacked the knowledge and skills to use online platforms. As a result, demystifying abstract

scientific concepts to develop conceptual understanding remained an arduous task for postgraduate science teachers. The implication is that these professional deficiencies underscore the need for coherent and sustainable development of teachers' technological pedagogical content knowledge. Enhancing technological pedagogical content knowledge would enable teachers to harness pedagogical affordances for online platforms in order to foster effective science teaching and learning. The sentiments from the interviewed postgraduate science teachers are encapsulated in the following excerpts:

Teacher 1 (Well-resourced school): *Online teaching is very effective if done right and if all learners are given resources to enable them to be able to participate.*

Teacher 2 (Poorly-resourced school): *I believe that online teaching and learning is not as effective as face-to-face teaching and learning. For instance, there are constraints associated with online learning and teaching, such as access to the Internet, and electronic gadgets such as laptops, smartphones, iPads, or computers. These constraints limit teaching and learning online.*

Most postgraduate science teachers indicated that the implementation of online teaching and learning was hampered by a lack of technological skills and a concomitant lack of technological resources. The postgraduate science teachers' conceptions of online pedagogical practices point to the need to put appropriate interventions in place to pave the way for teachers to be fully immersed in technology-enhanced teaching and learning. According to the teachers in poorly resourced schools, the Department of Basic Education ought to move with optimal speed to accelerate the provision of technological resources with a view to addressing prevailing socio-economic disparities within the system.

Theme 2: Context-dependent experiences in online teaching and learning

The postgraduate science teachers' pedagogical practices were largely context dependent. These factors included technological knowledge and skills, learners' abilities to access online learning platforms, the efficacy of online pedagogical practices to prepare learners for tertiary science-related courses, as well as the affordability of Internet connectivity for both teachers and learners.

Likewise, the postgraduate science teachers indicated that the use of virtual digital platforms posed enormous instructional challenges owing to contextual constraints. These constraints included access to technological devices, the availability of WIFI, prohibitive data costs, and connectivity issues. These sentiments are reflected in the following excerpt:

Teacher 3: *If I had means, I would have preferred to use Zoom or Google Teams where we would have some interaction. But it goes back to which devices learners have and if they do have access to data/Wi-Fi.*

The identified contextual constraints had an adverse impact on teachers' coherent implementation of adopted pedagogical practices. These fundamental challenges

could be addressed through the provision of unlimited access to bandwidth in schools to facilitate the implementation of online teaching and learning. Although some postgraduate science teachers appreciated the use of online teaching and learning platforms such as Microsoft Teams, Zoom, and Google Meet to facilitate virtual interactions, they bemoaned the poor attendance and participation by their learners. The teachers from socio-economically advantaged suburban and private schools pointed out that some of the learners deliberately skipped online lessons as a result of truant behaviour. This implies that meaningful implementation of online teaching and learning requires active parental involvement. Learners from disadvantaged areas were severely affected by connectivity issues as the following excerpt illustrates:

Teacher 4: *If I had the means, I would provide all my learners with efficient and sufficient connectivity and microkits from the school labs for them to partake in micro practicals.*

Postgraduate science teachers indicated that WhatsApp was the easiest and cheapest way to communicate with their learners and share notes and assessment tasks as the app consumes less data compared to the other interactive platforms. The elaboration is provided in the following excerpt:

Teacher: 3: *I had a WhatsApp group that I used to help learners and share materials. I interacted with my learners via the WhatsApp and they posted questions on the group and I tried to address them and assist them.*

Despite the challenges encountered, the postgraduate science teachers demonstrated resilience when navigating the vagaries of online teaching and learning. One of the postgraduate science teachers said the following:

Teacher 5: *I used mostly Microsoft Package to organize notes and presentations, and I used online tools like Google Classroom and Kahoot to assess the learners. I was also creating videos to explain difficult concepts.*

The transition to online teaching and learning posed formidable pedagogical challenges to postgraduate science teachers in diverse schools. These challenges are encapsulated in the following excerpts:

Teacher 6: *I found the design of authentic online assessment tasks difficult.*

Teacher 7: *I experienced poor learner participation during online learning as well [as] poor submission of online tasks.*

Teacher 8: *Identification of appropriate pedagogical strategies for online teaching and learning was problematic to me.*

The challenges encountered underscore the need for critical interrogation of enablers and constraints of online teaching and learning in diverse contexts.

6. Discussion

The participants expressed varied conceptions pertaining to online pedagogical practices. These conceptions are specifically related to their technical knowledge and skills, learners' abilities to access online learning platforms, the efficacy of online pedagogical practices to prepare learners adequately for tertiary science

studies, as well as the affordability of Internet connectivity for both teachers and learners. This finding is consistent with a study conducted by Das and Meredith (2021) which demonstrated that prior training on eLearning significantly influences effective teachers' adoption of online pedagogical practices. The sudden transition to online teaching and learning required resources such as Wi-Fi connections, laptops, and smartphones (Sari & Nayir, 2020). However, teachers' coherent adoption of appropriate online pedagogical strategies was hampered by a lack of technological resources for online teaching and learning. The prevalence of the COVID-19 pandemic critically exposed socio-economic disparities within the South African basic education system as postgraduate science teachers in poorly resourced schools struggled with learner participation and attendance owing to high data costs and lack of digital devices. These socioeconomic disparities served as constraints for meaningful access to bandwidth.

At another pragmatic level, the prevalence of the COVID-19 pandemic provided opportunities for teachers to embrace digital transformation as evidenced by teachers' appreciation of the exposure to the utilization of virtual digital platforms. However, teachers bemoaned the lack of professional capacity required for the coherent integration of technology in online science teaching and learning. Technology integration should be responsive to the dynamic nature of learning in terms of the three interconnected learning theories, namely (a) behaviourist, (b) cognitive and (c) constructivism (Celikoz et al., 2019). The provision of meaningful opportunities for the performance of practical work or investigations in online learning environments through the enactment of inquiry-based learning remained a formidable pedagogical hurdle for teachers. In addition, teachers encountered pedagogical challenges in the administration of technology-mediated assessments as evidenced by a lack of competence in the administration of online assessments. In the final analysis, the prevalence of the COVID-19 pandemic underscored the significance of the nexus between the development of 21st century skills and 4IR skills. While the pandemic disrupted teaching and learning, there is a need to harness opportunities that accrued from the prevalence of the pandemic to embrace pedagogical innovation in online learning environments. In fact, Baum and Dahlin (2017) posit that a crisis initiates learning and change using the knowledge and experience gained during the event itself.

The AS-TPACK framework provides insightful elucidation into the pedagogical dynamics associated with the provision of instruction in online learning environments. In terms of content knowledge signals, teachers encountered a myriad of pedagogical challenges in online Natural Sciences, Physical Sciences and Life Sciences teaching and learning. As part of pedagogical knowledge signals, teachers expressed varied impressions and experiences relating to the adoption of pedagogical strategies in online learning environments. In relation to technological knowledge signals, teachers bemoaned the lack of professional capacity required for meaningful and coherent integration of technology in online Natural Sciences, Physical Sciences and Life Sciences teaching and learning. The contextual factors that influenced technology integration in online learning environments were intrinsically linked to the socio-economic disparities characterizing the South African basic education system.

The empirical exploration is further underpinned by the multimodal model for online education proposed by Picciano (2017) as the underlying theoretical framework. As a theoretical lens, the framework is anchored on a learning community the key components of which are content, social/emotional aspects, self-paced/independent study, dialectic/questioning, evaluation/assessment, collaboration/student-generated content/peer review, and reflection. As key participants in the empirical exploration, science teachers constitute a learning community by virtue of their pursuit of a common goal to realize the stipulated educational outcomes of online teaching and learning. The teachers were overwhelmed by the complexity of pedagogical challenges encountered within online learning environments. A pervasive lack of technological resources hampered teachers' ability to deliver self-paced lessons and learners' ability to engage in independent study. Posing questions to establish learners' prior knowledge was increasingly difficult for teachers.

Furthermore, teachers expressed frustration with their lack of professional capacity to administer technology-mediated assessments in online learning environments. Connectivity issues also had an adverse impact on the provision of meaningful opportunities for collaboration among learners. Overall reflection on online teaching and learning activities revealed several pedagogical challenges that require attention in order to strengthen teachers' professional capacity for meaningful delivery of lessons in online learning environments. Key findings of the study demonstrated how science teachers in disadvantaged contexts could nevertheless embrace pedagogic innovation in online teaching and learning environments despite the scarcity of technological resources.

7. Conclusion

The key themes that emerged from the empirical investigation related to teachers' mixed conceptions about online pedagogical practices as well as the context dependence of teachers' experiences of online teaching and learning. Online teaching and learning posed formidable pedagogical challenges for science teachers. A pervasive lack of technological resources had an adverse impact on the effective delivery of instruction in online learning environments. There is a need to support science teachers when grappling with challenges presented by the sudden transition to online teaching and learning. Prevailing socioeconomic disparities characterizing the South African basic education system should be addressed as a matter of priority with a view to confronting social injustices within the educational space. Failure to address these socio-economic disparities adequately would serve to exacerbate the articulation gap between school and higher education. Enhanced epistemic and epistemological access would remain a pipe dream and this could hamper the human capital development required for achieving sustainable levels of economic growth. For science teachers to embrace digital transformation fully and pedagogic innovation by extension, concerted efforts are required to put appropriate strategic interventions in place that promote seamless navigation of the vagaries of online teaching and learning through the adoption of innovative pedagogical strategies. The provision of a globally competitive curriculum that fosters the inculcation of requisite skills through meaningful development of scientific literacy ought to be predicated on sound pedagogical principles and evidence-based pedagogical solutions. The

study was confined to a sample of postgraduate science students and the findings cannot be generalised. However, the findings have important implications for the understanding of pedagogical practices adopted in online learning environments in diverse contexts.

8. Recommendations

It is imperative to provide sustainable teacher professional development opportunities on the utilization of virtual digital platforms with a view to harnessing pedagogical affordances of online teaching and learning. Maximization of the academic experience of learners is central to the coherent achievement of envisaged educational outcomes. To this end, the Department of Basic Education should implore teachers to take advantage of available in-service professional development interventions providing meaningful opportunities for designing effective procedures for online teaching and learning. There is a need to enhance teachers' professional capacity required for the coherent administration of technology-mediated assessments in online learning environments. As key agents of educational change, teachers ought to be encouraged to embrace digital transformation fully to harness the affordances of various learning technologies. The realization of this key strategic imperative requires careful identification of enablers and constraints of both synchronous and asynchronous teaching and learning activities in online learning environments. There is also a need to provide adequate resources to disadvantaged schools and to provide concomitant professional development on the utilization of digital devices to stimulate meaningful online teaching.

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Appendix 1

QUESTIONNAIRE ON CONCEPTIONS AND EXPERIENCES OF ONLINE TEACHING AND LEARNING

Section A: Biographical information

Please place a cross (X) in the appropriate response.

1. State your gender.

Male	
Female	
Other	

2. Select your age range

20-24 years	
25 -30 years	
31-35 years	
36-40 years	
40 + years	

3. Which race group do you belong to?

Black	
Coloured	
Indian	
White	

4. Indicate the location/type of school in which you are teaching

Informal settlement	
Rural	
Farm	
Township	
Suburban	
Private/ Independent	

5. Indicate the subject(s) you are currently teaching.

Natural Sciences	
Physical Sciences	
Life Sciences	
Other (specify)	

6. Indicate the grades you are currently teaching

8	
9	
10	
11	
12	
Other (specify	

7. Indicate your teaching experience

0-5 years	
6-10 years	
11-15 years	
20 + years	

8. I mostly use the following gadget to access information or to teach my learners (choose one)

Cellphone	
Tablet/iPad	
Laptop	
Desktop	
Other (specify)	

9. My main source of connectivity is (choose one)

Data	
Wi-Fi	
Internet cafe	
Other (specify)	

10. How do you rate yourself in terms of ICT skills?

Excellent	
Very good	
Good	
Average	
Poor	

Section B: Postgraduate science teachers' conceptions about online pedagogical practices

a. What are your views about the effectiveness of online teaching and learning?
b. What are your views about the efficacy of pedagogical practices you adopted during online teaching and learning?
c. What are your views about the role of school management team in assisting you navigate online teaching and learning?
d. What are your views about the preparedness of your school for online teaching and learning?
e. In your view, what was the level of preparedness of learners and teachers for online teaching and learning?

Section C: Postgraduate science teachers' experiences of online teaching and learning

a. Describe your experiences of online teaching and learning.
b. What were the challenges you encountered during online teaching and learning?
c. How did you use ICT tools as part of online teaching and learning?
d. What are your professional development needs that must be addressed to pave the way for you to fully embrace online teaching and learning?
e. What lessons have you learnt from online teaching and learning?