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South African pre-service teachers' preparedness for fourth industrial revolution teaching and learning

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Abstract

The study's main aim is to explore the preparedness of a sampled group of South African pre-service teachers at a Higher Education Institution (HEI) to teach adequately in the Fourth Industrial Revolution (4iR) classroom. The study employed a case study research design to ascertain the level of preparedness of pre-service teachers (n=22) to use ICT tools for 4iR teaching and learning, using participant observation and focus group interviews. The Technological Pedagogical and Content Knowledge (TPACK) framework guided the research study in creating themes and analysing the data collected. The findings confirm that various aspects hindered the pre-service teachers from successfully implementing ICT tools in the 4iR classroom: school culture, inadequate computer infrastructure, and the need for the teacher education curriculum to be attuned to the 4iR teaching and learning. The study has thus significant implications on policy and practice in similar educational contexts around the need to develop appropriate intervention strategies towards advancing pre-service teachers' skills related to 4iR.

Keywords Education 4.0 · Pedagogy · Higher education · Mentor teachers · Information and Communication Technology · Policies · Higher order thinking skills

1 Introduction

In South Africa, there has been a recent and significant increase in interest in pedagogical activities aligned with the Fourth Industrial Revolution (4iR). The 4iR is predicted to shape the future of South Africa through its impact on government,

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industry, and the economy (Soni, 2019). A key aspect of the 4iR within the South African context is that the 4iR can alleviate challenges of poverty and unemployment (Olaitan et al., 2021; Waghid et al., 2019; Aluko et al., 2021) posit that the 4iR has the potential to positively influences Higher Education. The 4iR is further essential in creating enhanced platforms for online collaboration using cloud technology and the 'Internet of things (IoT) with the aim of continuing to foster real-time human interaction (HI) to maximise value creation (Hwang, 2016). By implication, teachers in the 21st-century should be aware of and attuned to the 4iR to ensure that students become global citizens in an ever more complex and dynamic society.

A preliminary literature review reveals a paucity of research on the kind of impact the 4iR has already had and is likely to have on education contexts in developing countries, specifically in the South African education context (Butler-Adam, 2018; Henama & Sifolo, 2021; Hlobo et al., 2021; Moloi & Mhlanga, 2021; Tengeh & Ogunlela, 2021). Particularly in the South African context, to succeed as a productive and competitive member of society in the era of the 4iR, high levels of numeracy and literacy, together with a thorough understanding of how the world operates, are essential (Butler-Adam, 2018). As a result of these and other claims and advocacy, the Minister of Basic Education in South Africa announced that three new school subjects, namely Robotics, Coding, and Kiswahili, would be introduced and piloted across 1 000 schools in five different provinces in the country in 2020 (BusinessTech, 2019).

In the South African context, as highlighted in a study conducted by Chigona & Chigona (2013), many pre-service teachers considered themselves to be under-prepared and under-equipped to teach in South African schools using ICT. Moloi & Mhlanga (2021) argue that teachers at rural schools do not see the value of implementing new technologies as many staff members did not receive formal training. This leads one to question how schools can transition towards the 4iR, despite many in-service teachers lacking the capacity to effectively implement even the most basic ICTs in schools. Undoubtedly, pre-service teachers' lack of preparedness and training to adopt e-Learning tools in their practice continues to widen the digital divide between affluent and historically disadvantaged schools in South Africa. This, although the Department of Higher Education (DHET) promulgated the Minimum Requirements for Teacher Education Qualifications (MRTEQ) policy document, which informs teacher education institutions on appropriate ways to develop their programmes and curricula. Concerning the use of ICT, MRTEQ specifies that a teacher's ability to utilise ICT for innovation in teaching and learning is fundamental to their teaching. Thus, in theory, all teachers should be competent in using ICT (DHET, 2015). However, according to MRTEQ, should a teacher be entering her/his preferred program of study without being ICT competent, the necessary steps should be put in place by the Higher Education Institution to develop the trainee teacher's confidence and skills in ICT (DHET, 2015). Also, despite the MRTEQ policy, Moloi & Mhlanga (2021) submit that the South African government must prioritise obtaining technologies to assist and facilitate teaching and learning in the 4iR.

It is against this backdrop that this study aims to respond to the following questions:

- RQ1: What is the nature and extent of the knowledge and understanding of these pre-service teachers about 4iR?
- RQ2: What, according to these pre-service teachers, are the foundational requirements necessary to teach effectively in a 4iR classroom?
- RQ3: What are these pre-service teachers' perceptions of what constitutes comprehensive preparedness to integrate ICTs effectively in a 4iR classroom?

2 Literature review

ICTs in education have remained an important area of interest to policymakers, researchers, and practitioners globally (Uluyol & Şahin, 2016; Pérez-Sanagustín et al., 2017) emphasise that pre-service teachers are the future of ICT use in schools in terms of their potential and capacity to use ICTs to stimulate higher-order thinking skills (HOTS) amongst their learners (Ndlovu & Lawrence, 2012). Therefore, Reyes et al., (2017), Bartolo (2017), and Gil-Flores et al., (2017) argue that initial technology courses are crucial in building the ICT competency of teachers. Reyes et al., (2017) see the ideal 21st-century teacher as one who becomes the expert teacher who possesses the necessary competencies for efficaciously using those ICTs required to support and enhance teaching and learning. Some literature has shown that integrating ICT in the classroom depends solely on the teacher (Buabeng-Andoh, 2019; Heggart & Yoo, 2018; Mwila et al., 2022; Ndebele & Mbodila, 2022; Vasant & Mehta, 2015). Because these authors argue that the ideal pre-service teacher to become the expert teacher regarding ICT implementation, the present study investigated what are those necessary 21st-century requirements the expert pre-service teacher should have.

3 4iR skills in the 21st-century

According to Banwari (2018), fundamental education reform from early childhood to primary and secondary education to vocational training and higher education will determine how the next generation of workers will find their place in the workplace across different scenarios. In this area, ICT and the preparation for the 4iR in education play a pivotal role in implementing appropriate teaching strategies and organising work to foster learning (Xing & Marwala, 2017; Banwari, 2018) postulates that individuals need skills to adapt to the 4iR - skills necessary to implement, manage, and work collaboratively with new technology. Hattingh (2018) describes these skills as workforce readiness, soft skills, technical skills, and entrepreneurial skills. This prompts governments, educators, and parents to ask how they can prepare present and future generations to survive and thrive in this rapidly transforming world (Brown-Martin, 2018). This resonates with the Department of Science and Technology in South Africa, which seeks to improve innovation and technology-driven change, together with the necessary 21st-century skills for students at Higher Education and Training Institutions to ensure that this change does not hinder the future

success of these students (Department of Science and Technology, 2019). Hence, Waghid et al., (2019) aver that university teachers and students should be re-skilled to use technologies in various ways. However, the readiness of South Africa to enable 4iR technologies is in question (Olaitan et al., 2021). Thus, Adesote & Fatoki (2013) argues that many developing countries continue to experience inadequate infrastructure and a lack of proper connectivity and reliable internet. We aligned our focus on policy implementation to address these inadequacies and the lack of proper ICT infrastructure.

4 Education 4.0

The 4iR has to be looked at in conjunction with Education 4.0. Education 4.0 is a response and aligns itself to the needs of 4iR (Hussin, 2018). Education 4.0 uses a combination of ICT tools to advance teaching and learning in the 21st-century. According to Puncreobutr (2016), Education 4.0 caters to society's needs in the innovative era. It thus aims at preparing university students for a changing and dynamic political, economic, social and cultural context (Waghid, 2019). Fisk (2017, cited in Hussin 2018) stipulates nine trends relating to Education 4.0:

1. Learning will take place anywhere.
2. Learning will be personalised.
3. Learners will be able to choose how they want to learn.
4. Project and problem-based learning be incorporated.
5. Learning will be integrated.
6. A computer will do data science statistical analyses.
7. Assessment methods will change.
8. Students will take responsibility for their learning.
9. Though students will learn independently, facilitating learning will be crucial.

Education 4.0 has further created a world where information is readily and ubiquitously available. It has positively disrupted teaching and learning, making it more dynamic (Halili, 2019; Hussin, 2018) argues that teachers need to repurpose their teaching approach to meet the need of the 21st-century teaching landscape. Based on this view, teaching with technology to support the learning process is the core concept of Education 4.0 (Hariharasudan & Kot, 2018). These authors predict that Education 4.0 will allow learners to learn at their own pace. New possibilities will be enabled when humans and technology are aligned (Hussin, 2018). Thus, in Education 4.0, technology-based teaching and learning, when utilised effectively, will provide for the needs of society in an innovative era (Hariharasudan & Kot, 2018).

In summary, this study will contribute to the discourse of 4iR in South African schools, looking specifically at policy and its importance in South African schools and international schools. In addition, this study is also apposite to the similar context in developing countries; therefore, it is relevant to the global audience.

5 Theoretical framework

The Technological Pedagogical and Content Knowledge (TPACK) framework was first conceptualised and introduced by Mishra & Koehler (2006) to illustrate the types of knowledge teachers need to teach effectively with technology. The framework builds upon and branches out from Shulman's Pedagogical Content Knowledge (PCK) (1986). Shulman proposed that pedagogy knowledge and content knowledge should not be seen as separate domains but that there should be a relationship between these domains (Mishra & Koehler, 2006). PCK was formulated to blend content and pedagogy in such an accessible way as to enable a grasp of how subject matter is structured, changed, and articulated for instruction (Mishra & Koehler, 2006:1021). These authors believed that the foundation of the TPACK framework is built using the idea of teachers being able to comprehend that teaching is a complex task that draws on a variety of knowledge. Thus, given this complexity, as Hofer & Harris (2012) point out, is it worth noting that not all subdomains of the TPACK framework may be present or emerge during teaching. Based on the development and evaluation of TPACK, Mishra & Koehler (2006), and Tallvid (2016), argue for an interwoven relationship between the domains. Mishra & Koehler (2006) endorsed the following relational elements to be important in their suggested framework:

- **Technological knowledge (TK)**. TK covers the basics of applying various ongoing maintenance aspects to a computer device, such as installing and upgrading hardware and software, maintaining a data repository, and keeping up to date with the constant technological changes. TK is a crucial knowledge construct in the 4iR (Mpungose, 2020).
- **Pedagogical knowledge (PK)**. It is a knowledge strategy used to implement and apply different assessment techniques to assess student learning. Mishra & Koehler (2006) also argue that teachers with a deep PK can understand how students build knowledge and acquire skills. Teachers with a deep PK can also foster effective thinking habits and positive attitudes towards learning amongst their students.
- **Content knowledge (CK)**. This is knowledge about the actual subject matter that is learned or taught. Because CK differs from grade to grade, the teacher must thoroughly understand the subject matter being taught (Mishra & Koehler, 2006). Hence, Mpungose (2020) argues that CK is a fundamental prerequisite for pre-service teachers.
- **Pedagogical content knowledge (PCK)**. This is knowledge about foundational areas of teaching and learning. PCK is the teacher's awareness of his or her subject matter and an ability to find multiple ways of teaching and develop and adapt instructional resources to build on students' prior knowledge (Mishra & Koehler, 2006). PCK is also the knowledge domain that seeks to improve teaching by creating connections across the different domains and improving the pedagogy to deliver the content (Mishra & Koehler, 2006).
- **Technological content knowledge (TCK).** This is knowledge about how technology and content are commonly related. TCK is knowledge about the development of technology tools for teaching purposes and understanding technology's

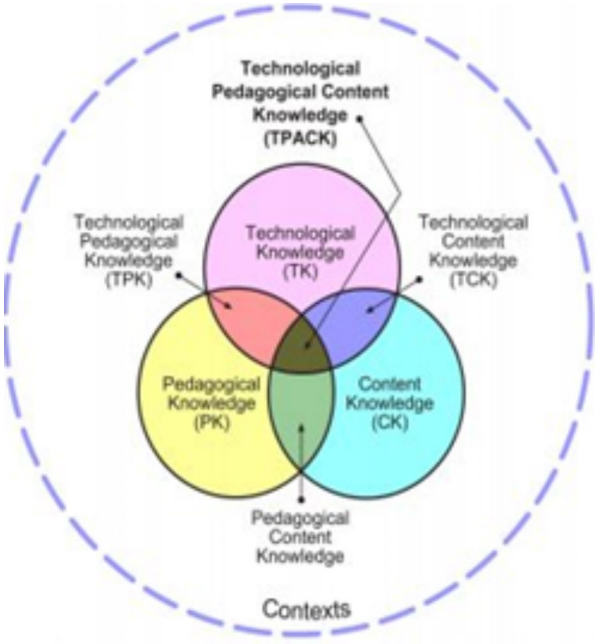

Fig. 1 TPACK domains—Reproduced by permission of the publisher, ©2012 by tpack.org

impact on this process. Also, TCK requires an in-depth thought process in technology to convey and enliven the subject matter (Mishra & Koehler, 2006). This thought process is guided by the lesson objectives, which ultimately inform the technology that can be most effectively used. TCK also allows the teacher to demonstrate how technology and content can complement or limit one another (Mishra & Koehler, 2006).

- **Technological pedagogical knowledge (TPK)**. TPK acknowledges that technology changes teaching and learning (Mishra & Koehler, 2006). TPK also requires a greater understanding of the existence and capabilities of technology within the subject matter in which they operate (Mishra & Koehler, 2006).
- **Technological pedagogical content knowledge (TPACK)**. This intersection and blend of all three knowledge domains (Fig. 1). Understanding TPACK involves realising that pedagogy, technology and content cannot operate in silos (Mishra & Koehler, 2006). Instead, these function together as an emergent form, and a teacher needs to understand how these domains complement and interact with each other. Applying TPACK in every lesson in which a teacher utilises technology requires understanding how subject matter can be represented using technology. In addition, TPACK includes an understanding of pedagogical methods that use technology advantageously to teach content — leveraging technology to teach complex concepts effectively and how technology can aid and facilitate students learning (Mishra & Koehler, 2006).

6 Methods

A case study design was used with a qualitative approach.

According to Nieuwenhuis (2016), qualitative data analysis is not seen as a number of successive or sequential steps, but rather as an interlinked process where the researcher follows a cyclical approach by going back to the field notes to verify conclusions. In addition, the qualitative approach allowed us to merge the data within the TPACK framework. A case study is considered the preferred research approach for examining contemporary events and collecting data within a specific context (Du Plooy-Cilliers et al., 2014; Yin, 2009; Zainal, 2007). A case study using many angles and different vantage points or perspectives allows for a rich picture to be built by the researchers by gaining analytical insights from such an image (Thomas, 2016). Thus, the case study design provided us with the opportunity to see and experience the particular phenomenon through the eyes of the research participants. This case study was further informed by interpretivism as it enabled us to gain an in-depth understanding of the phenomena through the lens of the person or persons being studied (Kivunja & Kuyini, 2017). According to Plooy-Cilliers (2014), interpretivists seek to understand and describe meaningful social action and experience as they believe that the reality for individuals is and is experienced, fluid and subjective and is created by human interaction.

In this study, data was gathered from the research participants who were purposefully selected (Fouché & Delport, 2011). Purposive sampling was chosen as this kind of research is based on the assumption that the sampled group's sample group of participants possessed unique qualities or characteristics in common (Etikan et al., 2016; Pascoe, 2014). Thus, the unique qualities which the 22 sampled participants possessed included:

(i) they were all Bachelor of Education (BEd) students.
(ii) they were registered for Computer Applications Technology, an elective module.
(iii) they had two years of pre-service teaching experience, in the course of which they obtained relevant ICT and computer literacy skills, and.
(iv) they had the experience of conducting their practice teaching at 'disadvantaged' and affluent schools throughout the Western Cape.

Furthermore, the participants were selected based on whether they had used or encountered an e-Learning tool from previous teaching experience at the schools where they had conducted their practice teaching. From the authors' analysis of the students' applications prior to their enrolment at this campus, it was found that 36% of the participants had not completed any form of computer literacy skills training during their schooling. In comparison, 64% reported having in-depth knowledge of computer applications. Their computer and information technology knowledge, experiences, and teaching practice experience made them suitable for selection for the study sample.

Focus groups were conducted to explore the participants' experiences and understandings regarding the use of an e-Learning tool, together with their understandings of the 4iR. Strydom & Bezuidenhout (2014) see the focus group interview as a valu-

able strategy for the researcher to determine the participants' attitudes, behaviour, and preferences regarding the studied phenomenon. Each participant was assigned a pseudonym (PS – A in focus group 1, PS – B in focus group 1, PS – C in focus group 1, etc.). The three focus group interviews (n=3) were guided by the following interview questions, which guided this article in its findings and discussion section: (i) "What do you know about the Fourth Industrial Revolution?", (ii) "What do you consider to be the fundamental requirements for teaching effectively in a 4iR classroom?", (iii) "What was your impression of how your mentor teacher implemented ICT tools in the classroom" (iv) "Can you recall a specific time during your teaching practice experience where a teacher made use of any e-Learning tools to facilitate teaching and learning? Describe this occasion." "What was your impression of, or what do you think the reasons were for, your mentor not using an e-Learning tool in the classroom." The participants' responses in the focus groups were coded in line with the TPACK framework underpinning this study. This was done to gauge the participants' TPACK level in line with their responses on the 4iR.

The unstructured observation method was further used for this study. These observations allowed us to become participants during the observation process. Strydom & Bezuidenhout (2014:180) list several critical benefits accruing to the researcher and their study in the observation(s), such as we became immersed in the reality of the participants, the researchers could note the behaviour participants would try and conceal. Another critical benefit of the observations was that incongruities might be picked up between what was observed during the micro-lessons and what was said in the interviews. A significant advantage of this was that the authors could triangulate the latter.

The observations conducted during the micro-lessons where the sampled participants were using e-Learning as a pedagogical tool provided opportunities for us to gain a more in-depth insight into how participants were using particular e-Learning tools. The authors took notes and observed the participants while actively using the specific e-Learning tool in the classroom. This created the opportunity for us to fully comprehend the participant's worldview regarding the implementation and use of technology, pedagogic approach, and decision-making process regarding the research context and obtain an in-depth understanding thereof (Queirós et al., 2017; Thomas, 2017). The TPACK framework was used as a guide to provide an investigative optic during the observations of the micro-lessons to ascertain why pre-service teachers would choose a particular e-Learning tool to meet their lesson objectives. The pre-service teachers' use of the elected e-Learning tool was measured against the TPACK domains.

7 Findings

7.1 TPACK results

The data collected and analysed regarding the cognisance of TPACK domains amongst pre-service teachers constitute a response to the three research questions. Table 1 represents descriptive statistics based on the research participants' total

Table 1 Descriptive statistics of TPACK domains

	N	Mean	
	Statistic	Statistic	Std. Error
Content knowledge (CK)	3	0.67	0.667
Pedagogical content knowledge (PCK)	3	0.00	0.000
Pedagogical knowledge (PK)	3	3.67	0.882
Technological pedagogical content knowledge (TPACK)	3	6.00	2.309
Technology content knowledge (TCK)	3	3.00	1.528
Technology knowledge (TK)	3	13.00	2.082
Technology pedagogical knowledge (TPK)	3	8.33	0.882
Valid N (listwise)	3		

responses to the question relating to the TPACK domains per focus group. This was to gain an overall idea of which domains were recorded as the highest. The full quotations (n = 129) were coded in line with the TPACK domains across the focus groups (n = 3). This was done to ascertain whether or not, and to what extent, during the focus group interviews, the pre-service teachers had a sense or knowledge of any TPACK domain and how they integrated these domains during their micro-lessons (n = 10) that the authors observed.

It can be deduced from Table 1 that the research participant's responses to the focus group interview questions focused mainly on TK (Mean = 13.00), TPK (Mean = 8.33), and TPACK (Mean = 6.00). The domains, namely CK (Mean = 0.67), PK (Mean = 3.67), and TCK (Mean = 3.00), were less frequently reported on during the focus group interviews and with no reporting on PCK with (Mean = 0.00). As a result, it can be argued that these participants lacked the capacity and experience to integrate technology into their pedagogy to strengthen their teaching. These results are similar to those reported by Chai et al., (2017). In their study of a group of sampled pre-service Chemistry teachers, the authors argued that the teachers lacked the experience and capacity to integrate technology in their pedagogy effectively in their lessons. The focus group interviews in the present study were used to validate the participants' micro-lessons ($n = 10$) that the authors observed regarding their understanding of the TPACK domains and the implementation thereof during their lessons.

7.2 Pre-service teachers' knowledge and understanding about 4iR

Table 2 presents the data primarily in response to focus group interview questions.

The participating pre-service teachers were asked the following focus group interview question to determine their knowledge and understanding of the 4iR: "What do you know about the Fourth Industrial Revolution?". Their varying responses to this question revealed that several pre-service teachers (n = 4) understood the 4iR to be linked to technology. The pre-service teachers in focus groups 1 and 3, respectively, reported:

Table 2 TPACK domains descriptive statistics - pre-service teachers' knowledge and understandings about 4iR

	N	Mean
Content knowledge (CK)	1	2.00
Pedagogical content knowledge (PCK)	1	0.00
Pedagogical knowledge (PK)	1	5.00
Technological content knowledge (TCK)	1	2.00
Technological knowledge (TK)	1	13.00
Technological pedagogical content knowledge (TPACK)	1	4.00
Technological pedagogical knowledge (TPK)	1	6.00
Valid N (listwise)	1	

"*I think the fourth industrial revolution is about using technology to make life easier*." (PS – E in focus group 1).
"*Fourth Industrial Revolution, in my opinion, is where artificial intelligence take over our work. For example, having a robot to deliver your food as we person with a smile can deliver it to you*." (PS – T in focus group 3).

These responses indicate that these pre-service teachers had a general and rudimentary understanding of the 4iR. For instance, these pre-service teachers reported simply that 4iR would make life easier and that technology advances at a demanding pace. These comments are further linked to TK, the highest coded domain with a mean score of $\bar{X}$ =13.00 (Table 2).

Some pre-service teachers commented that they did not understand what the 4iR is or entails:

"I do not have any knowledge about the Fourth Industrial Revolution". "*I also do not have knowledge about the fourth industrial revolution*". (PS – A in focus group 1).
"*I do not know anything about this. But I do not think it's going to go all uphill from there. I think it is going to be a tough road. Looking forward easy and tough*." (PS – U in focus group 3).

Only one pre-service teacher indicated some knowledge of the 4iR and its implications for the 21st -century and was of the view that the 4iR has the potential to disrupt the traditional classroom, shifting from sole reliance on face-to-face teaching and learning to more flexible teaching and learning environment premised on creativity:

"*Probably the first Industrial Revolution, the First Industrial Revolution introduced us to like education, formal education system because we had to educate people to work like in a factory. Right? However, today that is not the case anymore. The way they came from is a form and all that stuff, there are no more formal offices, everything is on the internet. And I would argue that in today's world, your creativity and job abilities are more important than your literacy, even if you can have three degrees. But if you can fight your way out of a paper box, like if you only have book knowledge, but you can when someone gives you a problem, you can go around the problem cause you don't know beyond the books. So it would help if you had creativity. Furthermore, I think this is*

the fourth industrial revolution, even beyond the technology and all that stuff." (PS – N in focus group 2).

According to this pre-service teacher, the 4iR applied within the education context is vital for creating opportunities for creative problem-solving skills, a group of skills ranked high on the WEF (2015) critical skills list. The pre-service teacher further contended that a teacher must engage theoretically with technology and technological practices. This finding is consistent with the theorising of Mishra & Koehler (2006) in terms of the various literacies, competencies, and character qualities both needed for and generated by engaging usefully with technology. These authors believe the implementation of technology and integration has the potential to stimulate problem-solving, which can be an effective way for teachers to develop their TPACK.

Some pre-service teachers indicated mainly negative understandings and perceptions regarding the 4iR, seeing it as being likely to replace teachers and other workers:

"…*the bad thing about the technology it can replace teachers in the long run and there will be a high rate of people without work*." (PS – H in focus group 1).
"*I think that even though the Fourth Industrial Revolution improves e-Learning, I think it will take over the place of the teacher self. And then we would not have jobs anymore*." (PS – K in focus group 2).
"*I also think it is going to be a disadvantage for us human beings because that people are going to lose their jobs and stuff. So yeah, it is a positive thing. However, it is also a negative thing. If you think of work-wise income*." (PS – P in focus group 3).

These responses indicate that certain pre-service teachers possessed some fear of the 4iR relating to teaching and learning. One reason for this fear having developed in these students may be certain students having a relatively low TCK and TPACK, which, according to Table 2, had mean scores of $\bar{X} = 2.00$ and $\bar{X} = 4.00$, respectively. Previous research by Hofer & Harris (2012) in a literature review has reported similar results. The authors noted that teachers needed further development in TCK and TPACK. The effects these authors reported are similar to the results of this study, as indicated in Table 2.

Furthermore, this was also the case in a study conducted by Maor (2017), where the author reported that TPACK was low amongst the participants in her study. The same results were yielded in a study conducted by Ślusarczyk (2018). Although her study was done in a business context and based on secondary data, participants' responses could be said to support the argument that the 4iR will not replace teachers in the education workplace but that, instead, the phenomenon is likely to create, and is creating, opportunities for more efficient ways in which information is being exchanged amongst people and objects.

Table 3 Research question 2 - TPACK domains descriptive statistics

	N	Mean
Content knowledge (CK)	1	0.00
Pedagogical content knowledge (PCK)	1	0.00
Pedagogical knowledge (PK)	1	3.00
Technological content knowledge (TCK)	1	4.00
Technological knowledge (TK)	1	13.00
Technological pedagogical content knowledge (TPACK)	1	8.00
Technological pedagogical knowledge (TPK)	1	11.00
Valid N (listwise)	1	

7.3 Pre-service teachers' perspectives of the foundational requirements necessary to teach effectively in a 4iR classroom

Table 3 presents the data primarily in response to focus group interview questions related principally to research question 2: What, according to these pre-service teachers, are the foundational requirements necessary to teach effectively in a 4iR classroom?

The participants were asked the following focus group question regarding this research question: "What do you consider to be the fundamental requirements for teaching effectively in a 4iR classroom?". Nine (n = 9) participants' responses emerged, indicating these participants agreed that ICT literacy is an essential requirement for learners to engage and teachers to teach effectively in a 4iR classroom. Pre-service teachers L and J in focus group 1 reported:

> "*I think the basic requirements are students and teachers are need to know how to use the basic computer use, or how to use the Word, how to surf the internet, how to use the application for e-Learning they are about to use for the class; they need to know it inside and out. So it is easier for the students to understand. And so they can answer all the questions that the students have*" (PS – L in focus group 2).
> "*I think that basic technical requirements for both teacher and learner is on computer literacy*." (PS – J in focus group 2).

From these responses, it is evident that, according to these two pre-service teachers, ICT literacy is a fundamental requirement for teachers and learners to possess in order for teachers to teach and learners to learn effectively in a 4iR classroom. This finding is consistent with the responses of pre-service teachers O and I in focus group 2:

> "*I would like to agree with pre-service teacher J. The teacher and the student both need to be the technology of need to be taught in, like, [a] crash course about the programme, which will be used in the classroom because, without the knowledge, the system will not work completely. I think the basic technical requirements for teaching effectively in a 4iR classroom is understanding how a computer works, understanding what the internet is, and how you will go*

about completing your learning through the e-Learning method." (PS – O in focus group 2).
"*I would like to acknowledge Student O because what she said is more that you can use a lesson before you use e-Learning in your class to prepare the learners more so that you know that your lesson would go fluently*." (PS – I in focus group 2).

These responses are a further indication of the importance of the context in which teachers find themselves. In their responses, some of the participants mentioned that computer infrastructure and technology knowledge (Table 3) play a critical role in teaching effectively in a 4iR classroom. Four participants (n=4) were cognizant of the importance of computer infrastructure, in particular internet connectivity and technological knowledge. Pre-service teachers K and U in focus groups 2 and 3 suggested that, before one can make use of ICT tools in the classroom, it is essential that one establish the school's network infrastructure, including connectivity to the internet:

"*I think the basic requirements before you can make use of technology in the classroom is listening to what internet in your classroom firstly. And learners should know how to work on computers, otherwise, the email is not going to work in the class.*" (PS – K in focus group 2).
"*For me, the basic technical requirements in a 4iR classroom would be to have a network, to have internet access and then to have computers, laptops, or learners can have their cell phones or tablets and an OHP or data-projector a smartboard, yeah things like that.*" (PS – U in focus group 3).

Interestingly enough, when participants were asked: "What was your impression of how your mentor teacher implemented ICT tools in the classroom?" the pre-service teachers reported the following:

"The students actually listened to the teacher; they communicate in class. It's not the teacher just sit there and talk material and they just sat there they're not taking in anything. They answered questions. They enjoyed what they were doing, Plickers. So every time a question end up everybody has questions. When someone gets something wrong, they debate why it's wrong. And so it wasn't like it just apply to us. Everybody was part of the class communicating with each other." (PS – A in focus group 1).
"My impression was that the use [of] Google Forms is very great way to examine the learner stands in each chapter of theory so that you can know where you should focus on, or where that learner is a little weak and where's that learner, what is that learners' strong part of theory? And then you can work from that, and then you can help all the learners in each chapter that they need help with." (PS – D in focus group 1).
"*In some classes where the teacher was computer literate, the classes went fluently; the students knew how to collaborate on the tablets. But in classes where the teacher was not computer literate, and did not want to do effort to … er …*

Table 4 Research question 3 - TPACK domains descriptive statistics

	N	Mean
Content knowledge (CK)	1	0.00
Pedagogical content knowledge (PCK)	1	0.00
Pedagogical knowledge (PK)	1	1.00
Technological content knowledge (TCK)	1	1.00
Technological knowledge (TK)	1	6.00
Technological pedagogical content knowledge (TPACK)	1	3.00
Technological pedagogical knowledge (TPK)	1	5.00
Valid N (listwise)	1	

have his skills … uhm … maybe become better in computer literacy. When the teacher did not do any effort for that at all you can see the impact it had on the children. They also did not want to improve their skills.“ (PS – O in focus group 2).

Based on the responses from these pre-service teachers, it can be deduced that the ICT culture in the classrooms where they were doing their practice teaching created a positive attitude, in both the learners and these pre-service teachers, toward the implementation of an e-Learning tool: the learners were more engaged in their learning, an observation on the part of these pre-service teachers, which supports the finding of a study done by Tynan and Barnes (2014). These authors are of the view that the implementation of e-Learning tools through an influential ICT culture has the potential to improve learner engagement with learning. Pre-service teachers' A, D and O also emphasised that different learning spaces were created for the learners to take ownership of their learning. Interestingly, this process was evident during the observations of the micro-lessons and what students both observed and perceived during their practice teaching when they attempted to implement ICT in their lessons.

7.4 Pre-service teacher's perceptions of the nature and extent of preparedness needed to integrate ICTs effectively in a 4iR classroom

Table 4 below presents the data in response to focus group interview questions primarily related to the research question 3: What is the extent of these pre-service teachers' perceived preparedness for them to be able to integrate ICTs effectively in a 4iR classroom?

Concerning the focus group interview question: "How do you feel about your preparedness to use ICT tools in a 4iR classroom?" six (n = 6) participants responded, while, on the other hand, most participants (n = 16) did not respond to this question. One reason may be that certain schools lack ICT infrastructure, thus preventing the integration of technology in their classrooms. This was confirmed by two students ($n = 2$), namely pre-service teacher J in focus group 2 and pre-service teacher V in focus group 3:

"*My preparedness to use ICT tools in a 4iR classroom. I think that you should not solely rely on computers. And you should always adapt to what the school has. So you must adapt to the school. If they do not have computers or projec-*

tors, you might need to be able to use posters and stuff. But If you do have computers, you must learn and educate yourself beforehand to use them successfully." (PS – J in focus group 2).
"*It depends on some of the ICT tools, and we feel comfortable, like a Quizlet, and that [is] where the kids can just click on the link and then they have the questions with them. But in some cases, we still have to learn a lot. Do it in classes. Depending on the school's infrastructure*." (PS – V in focus group 3).

Despite the lack of ICT infrastructure in several South African schools, the findings suggest that these pre-service teachers were cognizant of the need to advance their TPK $\bar{X} = 5.00$ (Table 4). Teachers should understand that 21st -century classrooms need to provide technology-supported teaching materials. There was also a sense amongst the interviewees of needing comfort in teaching with ICT tools. They thought they would resort to the ICT tools they were most comfortable with. The results further confirm that three (n = *3*) participants felt adequately prepared to teach using ICT in a 4iR classroom. Pre-service teachers A and H in focus group 1 and M in focus group 2 expressed themselves as generally prepared and confident to use ICT tools:

"I'm *prepared to use the ICT tools in a 4iR classroom. And since we have been learning about some of the tools from our second year. We have [had] to learn how to use certain tools, so I feel I am prepared to use some of the tools, but not all of them.*" (PS – A in focus group 1).
"*I would say I would feel pretty prepared about using ICT tools in a 4iR classroom. Because it depends on the school. The subject I took was bad. And my teacher was willing to teach me more than was just given in the handbook. And that prepared me for using information communication tools in the classroom. So it is now something I can adapt and use forever as a teacher also*." (PS – M in focus group 2).
"*I think I am also prepared to use ICT tools in a 4iR classroom, but if you come in contact with the new ICT tool, it is easy to read stuff up on it, how to use it, what it does and the features of it. So you can use it the next day and make it part of a lesson. So we don't have to use the same ICT tools every time. You can do research and find more ICT tools to make your lessons more interesting. So I feel I am prepared to use ICT tools*." (PS – H in focus group 1).

These participants appeared to be confident and sufficiently prepared to use ICT tools in a 4iR classroom. Pre-service teacher A pointed out that he had been exposed to ICT tools since his second year of tertiary studies, further acknowledging that, in this context, he considered self-discovery to be essential. This finding is vindicated by a micro lesson that the authors observed presented by pre-service teacher A on campus. He used particular e-Learning tools in his micro lesson, namely, Google Docs, Google Calendar, and Google Keep. The authors observed pre-service teacher A to be confident and prepared when he introduced these tools to the other students during the lesson. His body language indicated that he knew exactly what he was speaking about when using the application in the lesson. He demonstrated how Google

Docs could create documents for teaching and learning and how they explore tools in Google Docs that can be used to search for images for reuse for education and commercial purposes. In addition, he demonstrated how Google Calendar could be used to set reminders to assist with the timeous submission of assignments. Pre-service teacher A also introduced Google Keep to his fellow students as a note-taking application. This pre-service teacher explained that the notes created in Google Keep would be stored online for integration with Google Docs for detailed formatting and would be accessible from anywhere at any time.

8 Discussion

The study aimed to establish how a sampled group of pre-service teachers were prepared for 4iR teaching and learning. Based on the findings, most of the participating third year pre-service teachers felt that they were not prepared, or were insufficiently prepared, to teach in the 4iR. It was somewhat surprising that these pre-service teachers did not mention the other foundational competencies listed in the 2015 WEF report, namely, literacy (command of language skills), numeracy, scientific literacy, financial literacy and culture, and civic literacy as being integrally linked to using ICT effectively in teaching and learning. Pineida (2011) argues that students and teachers should develop technological and learning competencies as outlined by the WEF (2015) report to develop the kind of high-quality learning using ICT, mentioned in the literature review. The implication of this finding suggests a need for existing teacher education curricula at the undergraduate level to be critically scrutinised in line with the aforementioned foundational competencies. The authors submit that these competencies, albeit essentially listed individually in curricula, are interrelated. While ICT literacy is fundamental for effective ICT integration in teaching and learning, knowing, or being aware of, how students apply a core skill, such as (language) literacy to construct meaning from their everyday tasks, is equally essential when assisting students, using ICT, with their approach to complex problems. The possession of these competencies helps students direct how their learning will take place and encourages them to inspire and assist others. These competencies have the potential to ensure continuous engagement amongst students, allowing links to be drawn between instructional design and real-world experiences. Therefore, the authors submit that these are essential qualities for teachers to instil in a classroom as part of the project of advancing 21st-century learning and preparing their students to thrive in a transforming world. Given these findings, together with what is advocated in the literature, the authors submit that teacher education curricula and MRTEQ need to expand and to prioritise these qualities in order for these qualities to have a more direct and sustained impact on teaching and learning.

Furthermore, for teachers to buy into the use of technology at the school, there should be a clear and holistic ICT strategy that outlines different phases of ICT integration and usage in the classroom. An influential ICT school culture is of paramount importance for the following reasons: firstly it creates continuous growth opportunities. Secondly, it provides a space for students to become active 21st-century agents. Thirdly, it enables teachers to innovate and share ideas confidently with others in a

collegial way. In this context, Adesote & Fatoki (2013) argue that the appropriate, informed use of ICT can influence and change traditional teaching methods. Based on studies such as that of Adesote & Fatoki (2013), and the current study's findings, the authors of this present article contend that ways should be devised to assist teachers in seeing the significance of the use of ICT in the classroom in promoting digital equity. The authors believe this would potentially help to lessen the impact of the digital divide between affluent schools and historically disadvantaged schools, and help create a situation where every member of society has full access to technology and the capacity to use the technology. When teachers who serve as mentors, either formally or informally, at schools where pre-service teachers conduct their practice teaching use ICTs to promote and advance the 21st-century classroom, as mentors they create the opportunity and model for the pre-service teacher to do the same. This finding is in line with the gist of the 2004 White Paper on e-Education, which stated at the time that, during pre-service training, pre-service teachers should be capacitated in integrating ICTs as flexible tools to enhance teaching and learning (DoE, 2004). This capacitating also creates the opportunity for all stakeholders to collaborate in ICT initiatives that advance a teacher education curriculum; it creates the opportunity to lay the foundations for collaborations between universities and schools to ensure effective ICT implementation in the teaching and learning process.

The relatively poor level of preparedness for 4iR teaching and learning of a participating group of pre-service teachers is a source of concern. During our observations of their micro-lessons, it became evident that these pre-service teachers were underprepared for the use of technology for practical and valuable teaching purposes. The data analysed indicated that, while all of the participating pre-service teachers had a theoretical understanding of implementing ICT tools (TK) in the 4iR classroom, they were unable to practically implement an ICT tool (TPK) in ways that would integrate it effectively with the lesson objectives. They also failed to find the point of intersection between CK, PK and TK to demonstrate their ability to conceptualise how their stated lesson objectives during their micro-lessons were to be achieved using an ICT tool (PCK) (Table 1). In a context such as this, Chai et al., (2014) advocate the need for teachers to be design-oriented to leverage TK and PK for content learning.

The findings further indicate a need to advance pre-service teachers' TPACK domains for successful ICT integration in the 4iR classroom. This suggests that pre-service teachers strive to follow an essential substitution and implementation model to transition from traditional teaching pedagogy to a more 21st-century pedagogy. This approach would strengthen the pre-service teachers' utilisation of ICT tools and build their confidence. It would also create the opportunity for such pre-service teachers to critically scrutinise a particular ICT tool before its implementation during the forthcoming lesson. At the same time, the pre-service teacher would strengthen his/her TPACK domains. Pre-service teachers should also deepen their knowledge of the subject matter (CK) to be taught, as this forms an integral part of the successful implementation of ICT tools in the classroom. Therefore, the authors contend that pre-service teachers be better prepared in the aforementioned ways, to teach in the 4iR classroom, and that collaborative relationships between historically disadvantaged schools and public areas/resource facilities (libraries) and the private sector (internet cafes) need to be explored. When relationships between schools and these

stakeholders are adopted, it is envisaged that several of these schools would then be able to easily access the internet, thus creating online assessments for students.

9 Conclusion

The study concludes that some of the participating pre-service teachers were found to have a rudimentary understanding of the Fourth Industrial Revolution and its impact on education. This study also explicated that these pre-service teachers had only a theoretical understanding of the implementation of ICT tools for teaching and learning, thus reiterating the need for teacher education curricula to incorporate technological training to include and improve pre-service teachers' TPACK capabilities. This improvement or addition would include providing regular hands-on practical training and support for teachers using ICT tools in their classrooms. The findings in this article are subject to at least two limitations. Firstly, the sample size was too small. Secondly, the study only focused on pre-service teachers at one Higher Education Institution. Future research could look in more depth at the existing teaching and capabilities, and those needed by, and/or needing to be developed in, 4iR in-service teachers and what university educators and education departments are or are not doing concerning the improvement of 4iR teaching and learning. Exploring the nature of other university educators' 4iR implementations could assist those involved in teacher education to better understand what hinders and what promotes pre-service teachers' utilisation of ICT tools for teaching and learning, thus also creating a better understanding of the pre-service teachers' TPACK domains. Lastly, another potentially fruitful avenue for future research would be for a study to broaden its scope to include more than one Higher Education Institution, as part of a survey and/or for comparative purposes.

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Ethics approval Ethics clearance was obtained from the Faculty of Education Ethics committee.

Consent The participants were informed about the nature of this study and has given written consent to be observed and participate in the focus group interviews.

Conflict of interest None.

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