Rethinking Physical Science Practical Work in the remote teaching and learning context: A case of a South African University.

Name of Student: Tshegofatso Mashaphu

Student Number: 1259476

Protocol number: H21/10/28

Supervisors: Dr E. Mushayikwa

Co-supervisor: Mr SI. Zulu

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I. Abstract

This study focuses on exploring pedagogical and learning practices and approaches to practical work in the remote teaching and learning context. The aim was to investigate the physics practical work under remote teaching and learning conditions given that the practical work is traditionally laboratory based. The study used Technological Pedagogical Content Knowledge (TPCK) and Vygotsky's concept of Zone of Proximal Development (ZPD). This case study generated its data through the analysis of practical work manual documents and individual semi-structured interviews with participants. The participants included a physics education lecturer, a physics education specialist who was the consultant in charge of creating practical work manuals for remote practical work, 3 laboratory demonstrators, and 3 pre-service teachers. The findings of this study revealed that physics practical work was conducted in the form of kitchen-table experiments to give a sense of hands-on practical work to pre-service teachers Also, in the remote teaching and learning context, the designed practical work presented some Challenges for teaching and learning, even though opportunities were also imminent with this approach. Moreover, the findings indicate that several factors influenced the design, implementation and learning of the practical work. Such factors included network connectivity, limited availability/access of the recommended simple materials, and the preservice teachers' willingness to actively participate in the practical work sessions on the WhatsApp platform and lastly the findings suggested that the use of digital technologies was central to both teaching and learning practical work under the remote context.

Key terms: Science teacher education, Practical work, preservice teachers, teacher educators, Remote teaching and learning.

II. Declaration

I Tshegofatso Mashaphu (1259476) declare that this research study is my own work. It has not been submitted before for any other degree or examination in any other university. All the work taken directly from other works has been cited accordingly and the full list of references has provided. I fully understand that the University of the Witwatersrand will take disciplinary action against me if evidence suggests that this is not my own unaided work or that I failed to acknowledge the sources of the ideas or words in my writing.

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University of the Witwatersrand,

III. Abbreviations

AHPT- At home Practical Work

APW- Alternative Practical Work

B.Ed- Bachelor of Education

CAPS- Curriculum and Assessment Policy Statement

COVID-19- Corona Virus 2019

DBE- Department of Basic Education

DHET- Department of Higher Education

DIY- Do It Yourself creations

HEI- Higher Education Institution

ITE- Initial Teacher Education

KTPW- Kitchen Table Practical Work

NoS- Nature of Science

PCK- Pedagogical Content Knowledge

PGCE- Postgraduate Certificate in Education

PW- Practical Work

SA- South Africa

STEM- Science Technology, Engineering and Mathematics

TPCK- Technological Pedagogical Content Knowledge

UK- United Kingdom

ULMS- University Learning Management System

US- United States

ZPD- Zone of Proximal Development

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1.1. Introduction

What is science practical work without knowledge and action? Science practical work has been viewed as central in teaching science as such forms a great deal of teaching and learning science. The great debate in teaching science practical work reveals that practical work has evolved over the years and continues to be included in various science curriculum across the world (Millar, 2004; Needham, 2014). The evolution is influenced by few factors. One of the main factors contributing to the evolution is curriculum reform which occurs due to contextual local to global changes, for examples the COVID-19 pandemic affected the world's education tremendously (Mhlanga & Moloi, 2020). What does not change, however, is the fact that practical work is integral in science education, and remain to be emphasised (Tsakeni, 2022). Oliveira and Bonito (2023) stated "that the main idea on the concept of practical work is mandated to the manipulation of materials (being hands-on), and the main advantage of this methodology comes from the fusion between the development of practical skills and the conceptual understanding (minds-on)" (p. 1). Even though practical work is attached to the art of doing and knowing science, one of the main debates across the different science curriculum of this world is about how is practical work taught in science education (Millar, 2004; Mogofe & Kibirige, 2013; Asamoah & Aboagye, 2019; Tsakeni, 2022).

It is asked how do teachers incorporate practical work or how we do practical work for it to serve its purpose in science education, and lastly, it is asked where we do practical work (Gott & Duggan, 1996; Abraham & Millar, 2008; Perry & Wardle, 2011). Practical work is integral because science education community, even though not universally accepted, practical work as a central tool to teaching science (Hodson, 1990; Lubben & Millar, 1996; Johnstone & Al-Shuaili, 2001; Leung & Cheng, 2021). Johnstone and Al-Shuaili (2001) stated that it is widely but not universally accepted. Even though it is widely accepted Osborne (2015) still shares same sentiments with Hodson (1990), that practical work is overemphasised, ill-perceived and misunderstood by the science community. It is important to note that practical work is not universally incorporated into teaching science even amongst teachers teaching under the same curriculum. Muwanga-Zake, (2001) as cited in Mogofe and Kibirige (2013) states that "teachers in Eastern Cape do not incorporate practical work in their teaching regardless of having materials or not, and that the teachers had misconceptions about practical work as they continued to ask for more science equipment despite evidence of unused materials packed in their storages" (p. 426). Asamoah and Aboagye (2019) stated that teachers in Volta region in Ghana have accepted practical work as important for students understanding of science concepts, but they are not too sure on how to integrate it into teaching and learning physics. It is therefore, quite understandable as to why it would not be uniformly incorporated as the above scholars indicated that science practical work is not widely understood by the science teachers. Millar (2004) long ago also stated that practical work is not straight forward and it would be hard to box practical work into a certain definition or context or environment as it is broad. Millar (2004) further added that practical work is depended on the objectives of doing it. It would therefore need to be treated carefully from case to case, perhaps to the context of each science curriculum and pedagogies whether at tertiary or secondary level.

Regardless of its broadness and the misunderstanding, practical work has gained popularity over the years, as in recent education reforms, it has made its mark in the South African school science curriculum, where teachers are expected to include it in their teaching (DBE, 2011). This trend is not just in South Africa, but it has been so in the countries such as the UK, Australia and New Zealand, where it gained more popularity around the 1960 (Hodson, 1990; Oliveira & Bonito, 2023). With this booming popularity, it is at least appropriate to have teachers do it right if they are ever to incorporate it in their teaching, so there has been rising research and debates trying to answer to figure out practical work in science education, how it is perceived, how it is done, what it is its effect, how it is assessed etc (Millar, 2009; Shana & Abulibdeh, 2020). It has come to be understood that practical work is not the same, as such, it cannot be incorporated and measured in the same way (Millar, 2004; Abraham & Millar, 2008). It is maintained that practical work is meant to drive the understanding of the nature of science, amongst others, and that is aligned with the aims of science education. Practical work has been used to teach scientific knowledge and processes and has students gain scientific and practical skills. It has been used as a way of and also an environment for knowledge construction (Millar, 2004; Perry, & Wardle, 2011; Sshana, & Abulibdeh, 2020). Moreover, it has been proven to motivate and stimulate students interested in learning and mastering concepts in physics (Lee & Sulaiman, 2018; Sshana & Abulibdeh, 2020).

Then come into the picture the complexity of teaching and learning practical work for teachers and students when it is so different and mostly when it serves such a diverse purpose. Characterised by teachers' demonstrations in the classroom, learners' being hands-on in the laboratory/elsewhere, or open-ended/closed inquiry, practical work in science education has been a huge field of research and teaching and learning. As asked above, what is teaching science without the teaching of science knowledge-in-action? This refers to learning science by doing for learning, where the actions are somewhat linked to the cognitive development for better decision making, critical thinking and reasoning and problem-solving as community citizens (Heppner, 1996; Millar, 2004; DBE, 2011). Whether teachers or students do it, it is still practical work. However, it is believed that students getting involved and directing their own learning has boosted their confidence in science knowledge construction as they feel more like members of the broader science community (Millar, 2004; Gholam, 2019).

The continued research about science practical work is influenced by persisting findings, ranging from perception and experiences to environmental or socio-economic contextual issues of teachers and students, studnets' improved learning outcomes, and also declining enrolment stats which varies across the different science curriculum. Teachers and students can do practical work together or alone, depending on the approach or the kind of practical work chosen. The debates about teaching and learning practical work in science education continues, especially given the continuous evolution of the education landscape across the world due to the technological advancements and the socio-economic issues of different countries (Du, Sansing, & Yu, 2004; Kozma, 2011). To this effect era we have seen the evolution of where and how practical work is done, from the idea of a science laboratory to virtual labs and using the kitchen as a place for conducting practical work (Solomon, 1980; Myneni et al., 2013; Pols, 2020; Tsakeni, 2022)

Science laboratory work had gained fame as the one way to conduct practical work in the earlier centuries, however, the 21st century assured innovation and creativity, which meant outside-the-box thinking for practical science work. The physical laboratory work is rather now in competition with the thought of and created alternative ways to doing practical work. Alternative practical work refers to any other kind of practical work conducted outside of the designated laboratory with specific designed apparatus, which can either have teachers or students engage and construct science knowledge through the manipulation of objects or materials physically or virtually (Leung & Cheng, 2021; Myneni et al., 2013; Pols, 2020). Myneni et al. (2013) report on the virtual science laboratory that the technological advances brought forth, such as the interactive and intellectual learning system for physics education incorporating simulations and tutorials. On the other side of virtual or digital labs, other educators at the tertiary level in Europe speak of hands-on Kitchen table practical work where students are involved in scientific inquiry processes (Beans, 2020; Pols, 2020).

Alternative practical work (APW) is any type of practical work conducted not in the physical science laboratory or with sophisticated science apparatus, and others, such as virtual or digital labs, are applied due to the incorporation of technology in education. The APW has long been introduced in science practical work debates. However, they became more popular and were opted for due to the COVID-19 pandemic lockdown, where teaching and learning occurred remotely with the aid of digital technologies worldwide (Myneni et al., 2013; Beans, 2020). Pols (2020), in his study stated that his students were engaged in kitchen table open practical work where they had to create their own investigations procedures, and choice of materials. Teaching and learning occurred remotely more at the tertiary level than at the secondary or primary level in South African education. It then became interesting to me how prospective teachers are trained to teach practical work in the remote teaching and learning conditions for the South African school science curriculum. This study unearths how science practical work was approached by teacher educators and preservice teachers in initial teacher education, especially with the conflicting factor that SA school science is widely offered traditionally through face-face lessons. An instrumental qualitative case study approach was applied to unearth the teaching and learning of science practical work in science teacher education courses. Interviews and document analysis were conducted with teacher educators and student teachers to understand the design, implementation and learning of practical work for 3rd year physics teaching course and under remote learning conditions.

1.2. Background

Alongside the curriculum reform and rethinking conversation, there are technology integration in education conversations as well due to the advancement of technology and its impact in education and other sectors. Since the early 21st century, we have had policies addressing the incorporation or integration of technology education in both basic and higher education (DBE, 2004; DHET, 2013). Technology integration refers to using technological applications, tools and devices for access, communication, use of technology-based practices for teaching and learning, and administration (DBE, 2004). In the South African education sector, technology integration has found more expression in higher education than in basic education, though they both have had good policies (White Paper for Post-School Education and Training, 2013 and White Paper for e-Education, 2004) to outline how it looks in both contexts, respectively. The technology integration policies or frameworks are still being expanded upon in SA higher education due to its rapid advancement and continued impact on education delivery, such as blended, distance (open), online and now remote learning through online and non-online courses (DHET, 2013; 2017).

The covid-19 pandemic accelerated the use of technology, more especially digital technologies in education, where teaching and learning quickly shifted to remote learning as an emergency move (Bond et al., 2021). South African universities shifted toward online teaching and learning, and lecturers and students had to adapt to facilitating and learning via online platforms (Mhlanga & Moloi, 2020). Pedagogical strategies had to be revised. Some strategies included but were not limited to curriculum revision and the mode of teaching and learning, while the academic integrity of each course had to be maintained (Rusznyak & Robinson, 2020). Of concern was the science courses that offered laboratory work as one of the requirements to attain the qualification, such as engineering, physics, chemistry, etc. However, lecturers or course presenters had to adapt their pedagogic practices and approaches to the digital and online platforms, which also meant adaptation of practical work design.

The adaptation of teaching and learning was not a concern for only mainstream science courses such as Engineering but also for science teacher education courses where the student teachers are expected to know practical work, how to teach and assess it as the science curriculum requires them to teach practical work when they qualify (DBE, 2011; Chirikure, 2021; Raut & Gorman, 2022). Raut and Gorman (2021) stated that "remote learning forced universities around the globe to rethink their pedagogical models and adopt innovative strategies and approaches that enabled continuity of learning" (p. 80). Chirikure (2021) in a similar study as this mentioned that "reduced practical work or its complete loss would be significant in science teacher training where doing practical work goes beyond acquiring conceptual and procedural knowledge to include learning of how to teach through practical demonstrations, experimentation, and science investigations (p. 894).The teaching of practical work in science education is an art viewed as both a teaching and a learning strategy, meaning teachers have to be trained to teach practical work through practical work beyond understanding procedural and conceptual knowledge (Millar, 2004). Given the condition, the various approaches to practical work and the different researched factors influencing the teaching and learning of Practical work made it interesting to know how it was approached and experienced in South African university. Literature reflects mainly the response to science practical work in European, Asian and American countries, and most importantly, it reflects the response in a mainstream science course (Pols, 2020; Beans, 2020; Michael et al., 2021; Aththibby & Kuswanto, 2021; Raut & Gorman, 2022). However, there was limited exploration on teaching and learning of practical work in a teacher education course under the remote context, especially a focus on design of physics practical work for preservice teachers, as Chirikure (2021) explore preservice teachers' experiences in chemistry practical work in a teacher education course.

Teaching and learning of and through practical work across the world are different, and it is different for science teacher education as compared to engineering or mainstream physics or chemistry courses due to various factors. For teacher education, science is taught beyond knowing scientific skills and processes, but teachers are trained to teach practical work and through practical work to learners in schools (Millar, 2004). Given that practical work is both a learning and teaching strategy, students and teachers need to gain cognitive development about practical work in science education and its role. Also, practical work as a strategy for teaching and learning and know how to use it when they get to the classroom, starting in their initial teacher training (Hudson, 1996; Abraham & Millar, 2008; Chirikure, 2021). With the unexpected shift to remote learning and so much research outputs coming out and painting a picture of practical work in mainstream science and in other worlds it became of interest to me as someone who loves science practical work and a science teacher on how teachers are trained to teach practical and through practical in South Africa given the remote learning conditions and how it experienced by the student teachers.

Furthermore, as I was a science teacher and in the same university I am investigating at, I received training through traditional platforms. I had to do practical work in the laboratory where I was physically involved in the setup of the apparatus and chemicals and had the opportunity to conduct the practical work, observing and manipulating the studied objects in the laboratory. As a science tutor and a lab demonstrator to pre-service teachers, I wonder if students receive the intended science ideas in the online practical work, hence this study. I wonder if they have the same experience as with the physical laboratory session and are getting the skills and knowledge as intended by their lecturers. Does the nature of science change as teaching platforms change, or does online practical work achieve the aims of science education?

1.3. Problem statement

Zengele and Alemayehu (2016) report that the lack of laboratory and equipment hinders the incorporation of practical work in teaching science. However, the remote learning context factored out the laboratory and the sophisticated equipment since everyone had to be in their homes while they continue with the teaching and learning processes. The teacher educators and preservice teachers had to use their own spaces and transform them to suit the conditions presented by the remote teaching and learning context. Practical work plays an integral role in teaching and learning science and it continues to be central in science teaching with alternative approaches and practices being infused since centuries ago (Hodson, 1990; DBE, 2011; Sshana & Abulibdeh, 2020; Ferreira & Morais, 2020). Although, it is deemed integral in teaching science across the world, it still not widely incorporated in across the science curriculum. It is noted that practical work varies across board as reported in Millar (2004) and still is even today with different approaches to conducting practical as Tsakeni (2022) present the different approaches. And it was noted that there is confusion about practical work reported by Osborne (2015), as to what it is and why, how and where do we do practical work in science education.

Millar (2004) and Hodson (1990) stated practical work is relevant because the vastness of practical work is realised through the degree to which teachers use it (or not) in their practices and in how it is perceived or understood by the current generation of science teachers. According to Kibirige and Maponya (2021) teachers in South Africa view and use practical work differently in their practices. Beyond the understanding of what it is and how it is used, where practical work is to be conduted still have to be defined for different context due to socio-economical background of these context especially with the ever-changing or transforming curriculum or the changing and evolving education landscape. Change is inevitable and we keep rethinking ad redefining things with the change that also affect the education reforms. With its vastness either in what it is, how it is used or where it is done, teaching practical work at least needs to be done right, regardless of the contextual changes. Therefore, there is a need to keep redefining it with the changing context and conditions around it.

Ferreira and Morais (2020) state that “there are different factors affecting teaching and learning practical work. However, if used right, it should be an integral part of science syllabuses, pedagogic practices and assessment” (p. 3). Though teachers are meant to teach science practical work or science with practical work, literature still reflects teachers not incorporating practical work in South African schools (Mogofe & Kibirige, 2013; Oguoma, 2018; Gudyanga & Jita, 2019). Factors reported to affect or hinder the incorporation of practical work in South Africa are lack of resources, and teachers’ lack of confidence, lack of adequate skills and knowledge to do so, amongst others (Mogofe & Kibirige, 2013; Tsakeni, 2018). Of much interest in this study is on the rethinking of practical work for preservice teachers in a time where change is abrupt and continuous. That is, the focus is on how are preservice teachers engaged in practical work in this ever changing and digitised education landscape, looking particularly in a time when learning was remote in the absence of a physical classroom and laboratory for practical work. The objectives and interests of this study are also aligned with the Integrated Strategic Planning Framework for Teacher Education and Development in South Africa 2011-2025 (ISPFTED) and the Professional Development Framework for Digital Learning (PDFDL) for South Africa 2020. Which the PDFDL is also guided by the TPACK as a theoretical framework for the kind of knowledge base needed for a technology enhanced learning environment such as the remote learning context presented in this case.

It is therefore of paramount importance to understand how preservice science teachers in Teacher Education are equipped with skills and knowledge of practical work to teach for this national agenda. The national agenda is wide to a broader teacher education and always leaves it for research to break it into chunks of various subjects or components of the subject. In science teacher education it is not much explored especially how implementation actually translate to in Higher Education Institutions. Far less, from literature we know from what I have been presenting already that practical work is perceived and used differently in school. Mogofe & Kibirige (2013) state that SA teachers are less confident in teaching practical work and through practical and together with Oguoma (2018), equate this factor to inadequate teacher training to equip student teachers with skills and knowledge of teaching practical work. Perceptions and factors to incorporation of practical work is widely or at least known across research, but what is not known is how are prospect teachers engaged in practical work in Teacher Education

Even with the widespread view that teacher education is not adequately training student teachers to teach science practical work, little research has been done to investigate how pre-service teachers are trained to teach practical work. Also, much has been reported on the perception of preservice teachers on teaching practical work in SA schools. But not much is reflected on how they are trained to teach with practical work. That is, literature does not widely reflect much of the design, facilitation and learning of practical work for science pre-service teachers in South African universities (Kim & Chin, 2011; Tsakeni et. al., 2019, Mafugu, Tsakeni & Jita, 2022). The persisting factor that teachers are less confident in teaching with practical work needs to be resolved as the teaching and learning landscape evolves. The world's science education has introduced teaching and learning practical work with alternative ways to traditional laboratory practical work. The remote teaching and learning context pushes further the use of alternative practical work in sense that the laboratory and science apparatus are not so much of central factors. Alternative practical work means teachers are not restricted to highly sophisticated science laboratory apparatus and working in the specifically designed science laboratory. Hence, one way or the other, teachers need to be aware of practical work and be able to teach it and with it in any given context.

The development of new ways to do practical work date back to the early 21st century, if not prior, due to rising world developments that inform research to effect change in practice. Even so, the lack of resources and teachers' lack of skills and knowledge for practical work remains at the top when it comes the lack of incorporation of practical work in science education, especially in South Africa (Mogofe & Kibirige, 2013; Tsakeni, 2019). The rise of the COVID-19 pandemic did not make it easier for South African initial teacher education as the shift to remote learning implied unplanned and swift change in pedagogic approaches at the same time keeping the academic integrity of the course (Rusznyak & Robinson, 2020). This also affected science teacher education as the educators had to adapt their practical work component to the remote learning conditions. The transition to remote learning between 2020-2022 introduces new ways to teaching and learning and brought about innovative and creative thinking to teaching and learning. Though some institutions are going back to traditional ways of doing things, it cannot be disputed that the shift changed the teaching and learning approach for life for SA institutions of higher learning. And it deepened the crisis for teaching and learning practical work in science education as how teachers are trained to teach with practical work confidently remains unexplored in literature, especially as there are diverse approaches to practical work being introduced by the world. It is also important to note that the efficiency of these various approaches to practical work remains unclear, just as the effectiveness of the traditional practical is still immeasurable and unaccounted for (Abrahams and Miller, 2008; Constantinou and Fotou, 2020). So, while the debates on the effectiveness of practical work, in general, goes on, it is still regarded as central to teaching and learning practical work. And science teachers in SA are required to incorporate it in their teaching as a curriculum obligation. So, it is therefore important to contribute to literature on science practical work especially SA context by establishing a knowledge base for SA science teaching and learning of practical work in science teacher education to understand it and build knowledge ultimately to better equip teachers with relevant knowledge and skills to confidently and appropriately incorporate practical work with its various approaches in South African science classrooms.

1.4. The rationale and the significance of the study

Practical work is an essential part of teaching and learning science and has been part of the science curriculum since the mid-1850s (Gott & Duggan, 1996). It, however, gained much audience and popularity in science education in the 1980s, and from then, it became part of the science curriculum in most countries, that is, the US, UK, SA etc. (Hodson, 1990; Johnstone & Al-Shuaili, 2001; Bradley, 2005). As part of the science curriculum in many countries, it is accepted for its advantages in learning science. However, it is disadvantaged by many factors that impede its integration into teaching and learning science (Mogofe & Kibirige, 2013; Sshana & Abulibdeh, 2020). Practical work is important in science education as it is a teaching and learning strategy (Sshana & Abulibdeh, 2020). It is important because it is what science is all about and leads to a better understanding of scientific knowledge (Millar, 2004; Millar, 2009).

Practical work is one teaching strategy used in science education to drive the nature of science though the views and beliefs about the nature of science and practical work are not general across researchers, educators and students (Millar, 2004; Needham, 2014). However, it is widely believed that practical work support students in learning science through manipulation and observation of scientific phenomenon for understanding and knowledge construction (Lubben & Millar, 1996; Miallr, 2004; Said, Friesen & Al-Ezzah, 2014). The epistemological and ontological basis of practical work in science is that students should know what is known in science and how the knowledge was established.

It is believed that students learn better through practical work when they get involved in knowledge construction, where they become part of the science community and engage critically in science knowledge construction as it is believed to be tacit and not explicit (Millar, 2009). According to Millar (2004) "there is not a particular way to knowing science, so while there is a firm consensus about core knowledge claim, there is no consensus on how the science knowledge is established as such there need to be evidence provided to justify the explanation of what knowledge is in science ("p, 2). This is where students also get to be part of the knowledge construction in action through practical work. Practical work is said to improve communication, critical thinking, and problem-solving, invoke students' interest and motivate them to learn science in a world where its abstractness is perceived a difficulty (Miller, 2004; Park et al., 2016; Sshana & Abulibdeh, 2020; Constantinou & Fotou, 2020; Niyitanga et al., 2021). It is said to be one way of visualising science knowledge for students as it occurs in the natural setting (Millar, 2004; Park et al., 2016; Niyitanga, 2021).

While the advantages of practical work are mainly aimed at improving students learning, they have to be driven by teachers to be impactful. Teachers who are expected to teach with practical work need to ensure effective design and facilitation for practical work to be effective. Millar (2009) proposes an analytical framework to measure the effectiveness of practical work. However, effectiveness is not the focus of this study but the incorporation of practical work in teaching and learning science. The infusion of practical work in science teaching and learning is affected or hindered by many factors unique to the context of each curriculum. Though it is part of physical science CAPS 2012, it is still found that some teachers still do not use practical work for teaching and learning. In this study, of importance on the researched factors that are found to impact the incorporation of practical work in teaching and learning of science. These factors are teachers' lack of knowledge and skills, l as well as their lack of confidence to do so (Mogofe & Kibirige, 2013; Tsakani, 2018). Which they are linked to how teachers are prepared or trained to teach with practical work or how are they engaged in practical in initial teacher education.

Oguoma (2018) asserts that teachers' lack of knowledge and skills to properly incorporate practical work in their teaching and learning may be due to inadequate training during their preparation at ITE. Teaching and learning is a complex art that depends highly on the methods of delivery by the educator to serve the specific subject and the general learning objectives (Sshana & Abulibdeh, 2020). Literature does not reflect much on how teacher educators train preservice teachers to teach with practical work at initial teacher education. However, it reflects much on student teachers' perceptions about the role of practical work in science education. Student teachers are reported to agree that practical work is important in science. However, they have misconceptions about practical work, and they think that it is meant to verify existing science theories (Dikmenli, 2009; Mogofe & Kibirige, 2013).

Beyond the perceptions, which tell that teachers are indeed trained to teach practical work, we need the knowledge of how the preparation and training unfold. As a science teacher, I can attest to the fact that we are indeed trained to teach with practical work, but I cannot tell the extent to which that applies to the teaching and learning context in South Africa. I cannot tell, because I have not entered the classroom yet, to test my learning with classroom practices. Moreover, the reported misconceptions about practical work and factors hindering practical work incorporation may suggest that the training is not inadequate to respond to the South African school science curriculum with regards to practical work. Again, beyond knowing the factors hindering the incorporation of practical work in science teaching and learning, we need to find solutions to the lack of confidence, knowledge and skills to incorporate practical work. Which starts at most with exploring and understanding the problem itself, and we need to ask the question how teachers are trained with practical work or to teach practical work at initial teacher education. This is more important now in South Africa as the notion of teaching with practical work takes a broader shape to accommodate technological advancements in practice. Which the COVID-19 induced remote teaching and learning also enforced for incorporation and use even post COVID-19 induced learning conditions.

The continued development in the science education and transformation agenda has also assured innovation and creativity in science practical work. Various approaches were introduced to combat some challenges hindering practical work incorporation. Firstly, the laboratory as the environment for practical work became a non-factor as practical work extends beyond the laboratory. As such alternative practical work to traditional laboratory practical work became a reality and is now more popular in the current times where the COVID-19 pandemic accelerated use digital platforms as an environment where learning is facilitated and digital tools are incorporated into teaching and learning, most especially in Higher education institution (Mhlanga & Moloi, 2020). The environment for teaching and learning is slowly becoming a non-factor across higher education institutions which is a different case for secondary education in South Africa. This rather has implications for science teacher education with the practical work component. Literature does not greatly address how practical work in the current context and era looks or should look like for South African preservice science teacher in initial teacher education which ultimately feeds into secondary school science. What is rather clear is that science teachers in secondary education need to use practical work in their teaching (DBE, 2011). Therefore, there is a need to find out what is currently there in terms of teaching and learning with practical work at initial teacher education.

Tsakeni (2021), in her literature review, suggests various approaches to teaching practical work, including web-based practical work and DIY creation practical work. Pols (2020) and Beans (2020) report the approaches they have taken to ensure that their students continue with practical work during the pandemic: kitchen table practical work for Physics and Chemistry courses. Literature such as Pols (2020), Beans (2020) and Tsakani reflects the teaching and learning of mainstream science and engineering course or STEM in general and not specific science teacher education. Hence, this study is important to understand and reveal the approach to teaching and learning science practical work in South African teacher education. It is important to highlight that the study does not aim to generalise but to start or contribute to a knowledge base towards understanding how teachers are prepared and trained to teach with practical work in their initial teacher education. The teachers’ lack of skills and knowledge to incorporate practical work into their teaching and learning processes persist as a factor. However, many schools of education in the country and curricula makes practical work compulsory in teaching and learning science at the secondary level. Hence, the great need to unearth, first, how training looks like or what it addresses to prepare teachers to teach with practical work.

1.5. Key terminologies

Alternative Practical work- refers to practical work outside the designated physical or traditional science laboratory.

Consultant- The practical expert consulted to design practical work where simple materials had to be used for enquiry skills and knowledge construction.

Digital devices- They refer to gadgets used by students and teachers for their teaching and learning, respectively.

Digital technologies- refer to digital devices and tools the students and teacher educators use to access teaching and learning and digital content to enhance their science knowledge-based.

Digital tools are web-based or software apps that both students and teacher educators' access and use to mediate the teaching and learning processes. These are Simulations, YouTube, Ms Teams etc.

Initial teacher education- refers to the level of teacher professional development where the prospect teachers have never taken any teaching course before.

Kitchen Table Practical Work- refers to home-based practical work where students had to use materials that are generally found in the kitchen for scientific enquiry and science knowledge construction.

Lab demonstrators (Lab demis)/ Tutors- refer to the individuals responsible for facilitating practical work in this case.

Lecturer/Course Instructor- The individual who was designing and lecturing the course overall, the core teacher of the course, involved in all phases of practical work, responsible for teaching both theory and practical work of physics to the student teachers.

Practical work- refers to the tasks or activities designed for students to gain scientific knowledge through direct or indirect manipulation or observation of materials to allow for conclusions.

Remote learning- refers to the teaching and learning scenario where teachers and students are not in a classroom physically together, the concept that became famous during the COVID-19 pandemic regulations that required to work from home (remotely).

Science teacher education- refers to the B. Ed program aiming at training and preparing science teachers to teach either of the disciplines in the science field.

Student teachers- refer to students training towards becoming teachers (Science preservice teachers in this case).

Teacher educators- refer to all the individuals involved in either design and/or implementation of practical work.

1.6. Objectives of the study

The overarching aim of this study is to explore and understand the online tailored teaching and learning of physics practical work to 3rd-year pre-service science teachers. To be precise, the study objectives are:

1. To understand the nature of practical work taught and learned during the remote teaching and learning mode.
2. To explore factors affecting the teaching and learning of practical work during the remote teaching and learning context.
3. To explore teacher educators' and preservice teachers' experiences of teaching and learning physics practical work in the remote teaching and learning context.

1.7. Research questions

The current study seeks to answer the following research question: How does a South African University respond to physical science practical work in the remote teaching and learning context? To guide this study and answer the research question, the following sub-research questions were conceptualised.

1. What is the nature of physics practical work taught and learned in a teacher education course?
2. What are the factors influencing the teaching and learning of physics practical work?
3. What are the physics teacher educators' and pre-service teachers' experiences of practical work designed for remote teaching and learning?

1.8. Chapter Summary

The COVID-19 pandemic fast racked changes to the Education industry both at higher and basic education through remote working conditions, warranting rethinking of pedagogies and related approaches for continued teaching and learning. It is such impactful changes that give rise to education reforms and transformation both in the world and the in South Africa. The remote teaching and learning context accelerated the use of digital technologies, forced teachers and students to rethink pedagogical and learning practices for continuity. Under remote teaching and learning context, the physical laboratory and the equipment, as normally used for science practical work were factored and alternative approaches to practical work had to be put to effect. These included either, virtual labs, simulations, DIY, video analysis and kitchen table practical work amongst others. This study explored how teaching and learning of physics practical work occurs for preservice teachers in a South African University in the remote teaching and learning context. And these chapter introduced the study, presenting its contextual underpinnings, the standing problem of the study, its importance and the objectives thereof the study.

Following hereon, is five more chapters. The second chapter presents the debates presented in literature also identifying gaps not covered about practical work in teaching and learning science and the evolution thereof with the education reforms agendas warranted by various factors such as change in learning environment- the remote teaching and learning context and also the advancement of different technologies and changing times. The third chapter present two conceptual frameworks used as lenses for understanding the data collected in this study, these are the Technological Pedagogical Content Knowledge (TPACK) for exploring and understanding teacher educators' teaching approaches and practices from design to facilitation and the Zone of Proximal Development (ZPD) for exploring and understanding the learning of practical work. The fourth Chapter present the methodology of the study which used the qualitative approach, with the case study design, finding it stand orders on the interpretivism paradigm, data collection through document review and interviews and following spiral approach to data analysis from Creswell (2013) which is aligned with the inductive analysis approach. Chapter five present the findings, which reflect the nature of practical work designed and conducted by the teacher educators and preservice teachers respectively, the factors influencing the teaching and learning of practical work and the experiences teacher educators and preservice teachers had with practical work in this case. Lastly, chapter six answer the three research sub-questions and present some recommendations emanating from the study.

Chapter 2: Literature Review

2.1. Introduction

Practical work is a well-established teaching approach to science concepts in science education. Research has shown that there is alternative laboratory work that science teachers also consider at all levels of school science, including tertiary science, which is home-based and digital-based practical work (Pols, 2020; Gamange., et al., 2020). These are alternatives to the laboratory-based work that requires students or teachers to manipulate and observe objects used to understand the tested scientific concept in the science laboratory. This chapter first presents a general view of practical work and its role in science education, specifically the views of practical work as a teaching and learning strategy. Secondly, it maps out the teaching and learning of practical work, specifically focusing on the factors affecting the processes in science teacher education and science education in general. Thirdly, we explore the concept of practical work as an assessment tool in science education though the analysed data that did not reveal much on assessment. As such, it was not a discussed theme in chapter 6. And lastly, the chapter then presents reflections on the evolution of the concept of practical work, looking directly into how the concept of practical work has evolved over the years in how it is viewed and how it has been used by educators and students, especially with the changing landscape of education altogether due to the technological advancements of the 21st century.

2.2. Practical work and its role in science education

Practical work has been established as a prominent part of teaching and learning science. Millar, Marechal, and Tiberghien (1999) state that every science course at school and tertiary level should feature a significant portion of practical work. The notion presented by Millar et al. (1999) proves to be a development of the assertion made by Klainin (1988) when he alluded that practical work has been advocated for in science education since the 16th century though this is not a general statement because it is not widely accepted by the science teachers. Some researchers and curricula still advocate for practical work in science education (Abraham & Millar, 2008; Hofstein & Mamlok-Naaman, 2007; Hofstein & Lunetta, 2004). The South African CAPS (2011) requires physical sciences teachers to have formal practical work assessments with the learners at least once a term, with recommendations of the practical work activities for teachers to use. Hofstein and Lunetta (2004) highlighted, “science educators claim considerable benefits in learning accrue associated with practical activities” (p. 28).

Practical work is perceived as a strategy to drive understanding of scientific concepts, processes, knowledge and skills and not forget that it is seen as one way to motivate and invoke interest in students (Miller, 2004; Constantinou & Fotou, 2020). It is viewed as important because it is meant to have students engage with the nature of science on their own (Millar, 2004; 2009) suggests that students tend to become part of the science community as they construct their own knowledge through manipulating objects by themselves, as it is believed that scientific knowledge is known and constructed in action. Millar (2004) states that there is a general consensus on the scientific knowledge claims however, there is no general consensus regarding how the knowledge claims are validated or scrutinized. Students need to be involved in scientific enquiry processes through collaboration with peers, the teacher, or alone to be part of this big community of science knowledge creation.

The science laboratory has been the set environment to facilitate science practical work, with specific apparatus to help teach and learn scientific concepts until recent developments and innovation. "For more than a century, laboratory experiences have been purported to promote central science education goals including the enhancement of students' understanding of concepts in science and its applications; scientific-practical skills and problem-solving abilities; scientific 'habits of mind'; understanding of how science and scientists work; interest and motivation" (Hofstein & Mamlok-Naaman, 2007, p.105). Doing science alongside hearing and reading science is much more effective than just listening and reading science (Ates & Eryilmaz, 2011). That laboratory experience had students hands-on with science activities, doing science where students are directly involved in manipulating objects in the scientific experiments to enhance or gain knowledge of the concept in question (Haury & Rillero, 1994; Ates and Eryilmaz, 2011). It has also been asserted that practical work positively impacts students' achievements, just as laboratory work improves students' engagement in the subject as they construct knowledge by doing (Shana & Abulibdeh, 2020).

In contrast, Abrahams and Millar (2008), cited in Shana and Abulibdeh (2020), state laboratory work is seen as an ineffective way of teaching science, arguing that it does not present scientific concepts and concepts enquiry properly. As crucial as proclaimed, Gott and Duggan (1996) state that practical work is ill-defined, while Hodson (1996) followed suit and highlighted that with its position in science education, it is over-used and underused, and Osborne (2015) supports this notion by saying that practical is overemphasised and misunderstood. These two familiar debates about practical work prove to be permanent. The inquiry about practical work in science education continues even today. With the world's evolution and educational reforms, it is only ideal for the two ideas about science practical work to continue living. The exciting findings would be the ideas that would falsify the other side of the debate.

However, the above, contrary studies about the role and importance of practical work do not dispute that practical work Is central to science education. They merely question the role of practical work in science education and its effectiveness as a teaching approach in science education. Gott and Duggan (2007) propose a framework for practical work in science teaching with an argument that there needs to be a way forward and an attempt to contribute to the debate that practical work is primarily evidence-based. While there is a team trying to define the role of practical work in science education, I believe a team has defined practical work and its role and is now working toward refining and improving the effectiveness of practical work in science education. What has come out that is very important and makes this notion of practical work in teaching science is that practical work is not the same. Millar (2009) states that "practical work differs considerably in what they ask students to do and what they are trying to teach" (p. 1). Therefore, some degrees to practical work have made it difficult to measure its effectiveness for universal acceptance in science education.

Practical work in science education is presented as diverse activities. While research defines and differentiates these activities, the priority or much focus is given to defining, explaining the aim and improving practical work to make it more effective for teaching and learning science (Gott & Duggan, 2007; Millar, 2004; Abrahams & Millar, 2008; Hodson, 1996; Abrahams, Reiss & Sharpe, 2014). As presented in (Gott & Duggan, 1996), the notion of practical work as experimentation is no longer as strong as it used to be. Practical work in science education now speaks to open or closed inquiry approaches which are further engaged differently. They include demonstrations that may take videos, diagrams, or teachers demonstrating certain science concepts during the lesson, students being hands-on with materials, web design, and computer simulations (Hofstein & Unetta, 2004; Gott & Duggan, 1996). The idea of practical work as in laboratory work is in line with students having to be heavily involved and hands-on during the lab session, observing, manipulating objects and interpreting findings for themselves; however, that can still happen outside the laboratory (Millar et al., 1999; Millar, 2004; Tsakeni, 2022). The hands-on mode of practical work is considered not enough. It needs to be paired with the mind-on. Millar et al. (1999) present the notion that practical work is impactful when students are greatly involved in doing practical work themselves with the four domains framework they created for effective practical work. Abrahams (2017) support the notion by stating that learning through practical work is more impactful when students than when they just read or watch. It is worth noting that, just as practical work comprises the hands-on and the mind-on, which speak to NOS and NOSI, so much of the aim of practical work as in the hands-on is not clarified. Millar (2004) suggests that "in as much as it is asserted that practical work brings students' understanding closer to the scientific community, it is not so clear as to whose idea on how to do science student should understand" (p. 2).

2.3. The teaching and learning of practical work in science (physics) education.

Gott and Duggan (2007) acknowledge that there will be no obvious way forward in the debates about practical work. Indeed, with the science curriculum transformation warranted by the digital world we live in today, the various socio-economic and sociocultural factors impacting the curriculum and the teaching and learning thereof, practical work will be a concept viewed and experienced differently across the world's science curriculum. However, before diving into the issue of the evolution of practical work in science education, it is much more helpful to investigate the use of practical work in the teaching and learning of physics or, rather, the teaching and learning of physics practical work and the factors affecting the processes thereof. Banu (2011) states that as a physics lecturer, as much as practical work is an integral part of science education, not much of it is infused in teaching physics. He highlights that it is mostly in developing countries where there is not much practical work integrated into teaching physics, and most students do not understand physics knowledge. I could agree in that, as in my high school experience, practical work was done much more in chemistry than in physics, where we would go to the chemistry labs most often to do chemistry practical work than we would engage in physics practical work. However, the experience in my teacher education days was different in that physics practical was really integral in our training.

Banu (2011) and Vilaythong (2011) highlight that physics teaching is much more traditional, with little or no incorporation of practical work. Banu (2011) asserts that physics is perceived as an abstract subject challenging to understand, and most learning is done through memorisation of the taught physics concepts, facts and principles. The abstract nature of science I believe is what warrant the need for practical work to make the content relatable to students and to allow students to actively construct their own knowledge of the subject matter (Niyitanga, Nkundabakura, & Bihoyiki, 2021). Benjamin Franklin writes,

"Tell, and I forget. Teach me, and I remember. Involve me, and I learn". (Extracted from Lopez-Rosenfeld, 2017)

The limited amount of practical work in teaching and learning physics is quite alarming because there is low performance and enrolment in physics subjects and the low performance persist especially where practical work is not infused into the teaching and learning processes (Banu, 2011; Kola & Taiwo, 2014; Twahirwa & Twizeyimana, 2020). Banu (2011) reports a drop-in student taking pure physics in India from 30% in 1950 to 20% in 2000. The decrease in physics enrolment trends was also reported for Nigeria and Kenya (Adolphus, 2016; Aina & Adedo, 2013; Munene, 2014; Omar, 2017). Scholars reported that there has been a continuous decline in enrolment in science especially for physics (Aina & Adedo, 2013; Munene, 2014). Twahirwa and Twizeyimana (2020), in their study to investigate the impact of practical work in students' academic performance of the secondary school in Rwanda, found that the students in the experimental group outperformed those who were in the control group. Practical work is reported to ignite students' interest in the subject and also encouraging active participation and self-directed knowledge construction (Niyitanga, Nkundabakura, & Bihoyiki, 2021).

However, they note hindrances to teaching and learning practical work, which is not new to research, and it always mounts back to limited or no integration of practical work by teachers. Vilaythong (2011) and Babalola, et. al. (2020), reported that the lack of practical work in physics education is due to the lack of skilled teachers and proper equipment because the science curriculum covers and emphasises practical work. This is also reported in the South African context, where Mogofe and Kibirige (2013) state that the lack of incorporating practical work in teaching science in SA schools is not limited lack of resources rather, it extends to teachers' lack of knowledge and skills to appropriately integrate practical work in their teaching. Which is linked to the inadequate preparation in initial teacher education (Oguoma, 2018). Tsakeni (2018) also reports on the contextual and socioeconomic factors that affect incorporating practical work. These factors include the environments and background for which the school is located, lack of resources, the affordability to build laboratories and equipment (Tsakeni, 2018). All these assertions are not far-fetched as they are also reflected in international literature. The preservice teachers interviewed in this study also indicated that teachers' incorporation of practical work in high secondary school science is not the same, as one were not exposed to practical work at secondary school. At the same time, the other had teachers read the supposed practical work from the textbook and ask learners to imagine the actual processes of conducting practical work. The other students had an experience where the teacher engaged them with practical work through improvised materials. These different experiences may be linked to different backgrounds and contexts in which the schools and students are involved.

Of notice is that the literature engaged in for this section, reflect the complexities of the practical work incorporation in secondary science space across Africa and the world. The knowledge gap identified is that there is limited literature reflecting the dynamics of the teaching and learning of practical in teacher education courses. Literature explored reveal a knowledge gap that need to be closed about teacher education. It is not enough to just highlight that teachers don't infuse practical work in science teaching and learning, teachers lack skills and knowledge to integrate practical work in their teaching, when we do not have bases of how they are engaged in practical work in teacher education especially now that the education landscape is ever changing demanding creativity and innovation in pedagogical strategies and practices.

2.4. Practical work and assessment in science education

While practical work has been portrayed as a teaching and learning strategy, it is assessed to see rather check for the effectiveness of practical work. We have seen research suggesting that practical work helps improve students' achievements or performance in science subjects (Sshana & Abulibdeh, 2020; Twahirwa & Twizeyimana, 2020). The outcomes of teaching and learning are measured through assessment in school's curriculum across the world, and as such practical work as a teaching and learning tool has its own dynamics around assessment. The dynamics, however, are viewed to be unclear and not specific. This is affected by the unspecified components of the aims of practical work, which is the enquiry processes that practical work has to facilitate amongst other knowledge and skill sets in science education (Hodson, 1993). According to Millar (2009), Practical work in science education embodies the linking of the idea domain and enquiry domain (Millar, 2009). Then practical work becomes an exciting but complex idea because the science community agrees upon the science ideas being driven. Still, the enquiry processes are open to being unique to the member who is involved in the knowledge construction process (Millar, 2004).

This flexibility translates into the complexity of the idealisation of incorporating practical work in science education. There is little or no agreement on the enquiry processes. It is most likely that they might not get on with what one is unsure of. However, the fact that the scientific ideas are confirmed makes it easier to conceptualise and engage students in practical work as it can serve various purposes hence the openness of its' scope and at the teacher's discretion

(Ndyetabura, 1982). The purpose and effectiveness of which science education are measured through assessment. Due to the flexibility behind what an enquiry skills or practical skills is, the notion of assessment gets questions on its purpose and effectiveness as well (Ndyetabura, 1982; Hodson, 1993). Abraham et al. (2013) suggest that "for practical work assessment to be effective, it is much more relevant to know and understand what is being assessed" (p. 3). Hodson (1992) presents four functions of assessment procedures in science education, which are summative, formative, evaluative and educative functions. However, these functions are reported to be poorly performed and overshadowed by the notion of ranking and grading (Hodson, 1992). We have seen in recent research that most practical work is mainly incorporated into the school science curriculum to improve students' performance or achievement in the science subject (Mogofe & Kibirige, 2013; Oguoma, 2018; Sshana & Abulebdeh, 2020). The notion of grading and performance being at the centre of assessment was also confirmed by the students in this case, together with the teachers' educators, to say in the setting that they were exposed to learning practical work was not as effective the only thing students were concerned about was to obtain marks which the teacher educators did not have control over.

Nonetheless, teachers have control over the assessment design, which may serve the functions presented by Hodson (1992). The assessment aims regardless of the kind practical work being explored. If well formulated and communicated, the assessment can effectively achieve its primary goals and ultimately feed into students' performance (grades) in science subjects. According to Erduran et al. (2020), the design of the practical work embodies what is being assessed at the end of the day. That is, the design of the practical work task should communicate the learning objectives, as in what the students need to have achieved or learnt when they are done with the task (Hodson, 1993; Abraham et al., 2013). This also comes out in the practical work the teachers choose to have the students engage in.

2.5. The evolution of practical work and education reforms

Global transformation and development introduced technology as a force for smooth and convenient operations. The 21st century made it a norm that digitisation is indeed the present and future of this world, which has been accelerated by the COVID-19 pandemic regulations.

Even so, technological advancements see a slow implementation in developing countries. Digital divides in developing countries are at a peak in that the inequalities put those in rural areas do not afford the devices to talk less of the internet coverage in their areas. Educational reforms in the digital era nevertheless speak of technology integration in teaching and learning both in basic education and higher education (DHET, 2013; DBE, 2004). The HEIs in South Africa received a mandate for online and blended learning from the department of higher education in the white paper for post-school education and training in 2013. The slow implementation of this policy saw an acceleration by the COVID-19 pandemic in the previous year when universities suddenly shifted to online learning (Mhlanga & Moloi, 2020).

Implementing the policies on technological integration affects the teaching and learning process throughout the programs. It does not leave out science education, even with its practical nature, with practical work at the centre of science teaching and learning. Practical work is said to be conducted in a science laboratory (Solomon, 1980); however, the digital era has shown a twist of events where a science laboratory is not feasible in some parts of the world. In an instance where practical work in the laboratory is not possible, teachers must come up with various other strategies to have students do science whether in a traditional schooling context or online context. There is a rise in alternative practical work over laboratory work (Leung & Cheng, 2021).

Moreover, practical work in the laboratory is quite expensive compared to other forms of practical work. It is also reported that laboratory sessions take time before satisfactory completion of the activity and are bound to the school hours and premises. While on the other hand, alternative practical work gives students time to do the practical even beyond school hours and does not consume much time (Leung & Cheng, 2021). While procedural issues are reported on, teaching and learning strategies and approach on the alternative practical are not reported, especially in developing countries where both laboratory sessions and alternative practical are challenging. More of what is reported is really preservice teachers' experiences in learning alternative practical work (Chirikure, 2021). The lack of resources in most schools has seen teachers factoring out the practical work component, especially during the covid-19 pandemic. While other lecturers chose computer simulations for practical science work, others chose kitchen table practical work for their students, where students had to do science one way or the other (Pols, 2020; Leung & Cheng, 2021; Beans, 2020)

Practical work evolves more in a similar way across the different science disciplines, especially with regards to the general aims of science (Millar, 2004). However, less so with how it is incorporated in these different disciplines and this as alluded to by Millar (2009) is because the objectives behind the teaching and learning of practical work is dependent on its objectives. It has across the disciplines moved from just having students observe science phenomenon for understanding, refutation or confirmation in recipe following closed investigations to also including open investigations (Abrahams & Millar, 2008; Millar, 2020). Oliveira and Bonito (2023) stated that "Programs such as the Biological Sciences Curriculum Study (BSCS) and the Earth Science Curriculum Project (ESCP) establish that in addition to their content, the Biological Sciences and Geosciences programs, respectively, should reflect, from that moment on, the science enterprise in its broadest scope, adopting a more investigative spirit, contrary to its teaching as mere observational sciences" (p. 2). Pols (2020) reported that his students created their own investigations while in this and this was also the case for Bean (2020). The literature, reveal that practical work continues to be redefined especially for students to be drivers of learning to use the popular terminology, it advocates for student-centred learning as inspired by the work of theorists Vygotsky, Piaget and Dewey who believed that learning is as experienced in context. The approach to teaching and learning practical work may have evolved, however, the it is still embedded in the general aims of science as alluded to by Millar (2004) and that is the focus is on science conceptual understanding, practical and procedural skills, scientific enterprise, and actual manipulation of materials (Oliveira & Bonito, 2023).

Chapter 3: Understanding teaching and learning of practical work through Technological Pedagogical Content Knowledge and Zone of Proximal Development

3.1. Introduction

So much of what is put forth as knowledge is conclusions from analysis of set evidence gathered through research. However, these analyses are informed by formulated analytical tools grounded on a set theory or theories or concepts that researchers develop or borrow from other researchers that came before the current study is done. This study use Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006) and the Mediation concept through the lens of the Zone of Proximal Development (ZPD) (Vygotsky, 1986) as a conceptual framework to analyse the data to be collected. In research, we have a theoretical and conceptual framework as lenses to viewing and understanding a phenomenon. A theoretical framework is defined as the lens used to understand and explain the relationship between the observations and the epistemological stance of the observed phenomena. Collins and Stockton (2018) describe a theoretical framework as "a way of explaining how things work" (p. 1). Silver (1983) defines it as a specific way of knowing what is, a reflection of someone's lens of seeing the nature of the object or subject. "A conceptual framework represents the organisation of central ideas and central concepts from theories, key findings from research, policy statements and other professional wisdom that guide the research project" (Shikalepo, 2020). While some scholars would say these two concepts refer to the same things, this study uses the term conceptual framework as certain concepts of a broader theory were used to view and understand data in this study. TPACK is a concept based on and extended from PCK theory (Shulman, 1978) and ZPD is a concept based on a broader Sociocultural theory (Vygotsky, 1986).

Technological Pedagogical Content Knowledge and the Zone of Proximal Development were used in this study to allow for a greater understanding of the teaching and learning of practical work and through practical work in the Physics teacher education course in the remote learning context. TPACK provides a greater understanding of only the teaching of and through practical work and in the COVID-19 pandemic-induced remote learning. The sociocultural theory's ZPD allows for a greater understanding of the learning of and through practical work and the relationship between teaching and learning for development.

3.2. Technological Pedagogical Content Knowledge (TPCK)

TPACK, as appearing in many articles (Schmidt, Baran & Thompson, 2009; Chen & Hsu, 2019), is a framework formulated to extend Shulman's Pedagogical Content Knowledge (1986). Shulman (1986) proposed that for effective teaching, teachers must possess a specialised knowledge of the subject matter and how the subject matter is presented to best suit the varied interests, knowledge, and abilities of learners PCK. Mishra and Koehler (2006) then proposed the TPCAK framework to contextualise 21st-century teaching where the process is beyond incorporating varied technologies to influence learning. They propose integrating technological knowledge, as in Shulman's PCK, which broadens the scope of teaching in the current times. They proposed that teachers must have three knowledge components interconnected to drive learning, which are: Content Knowledge (CK), Pedagogical Knowledge (PK) and Technological Knowledge (TK). These knowledge components are then interlinked to give three knowledge relationships that make one main component of knowledge driving learning in the 21st century.

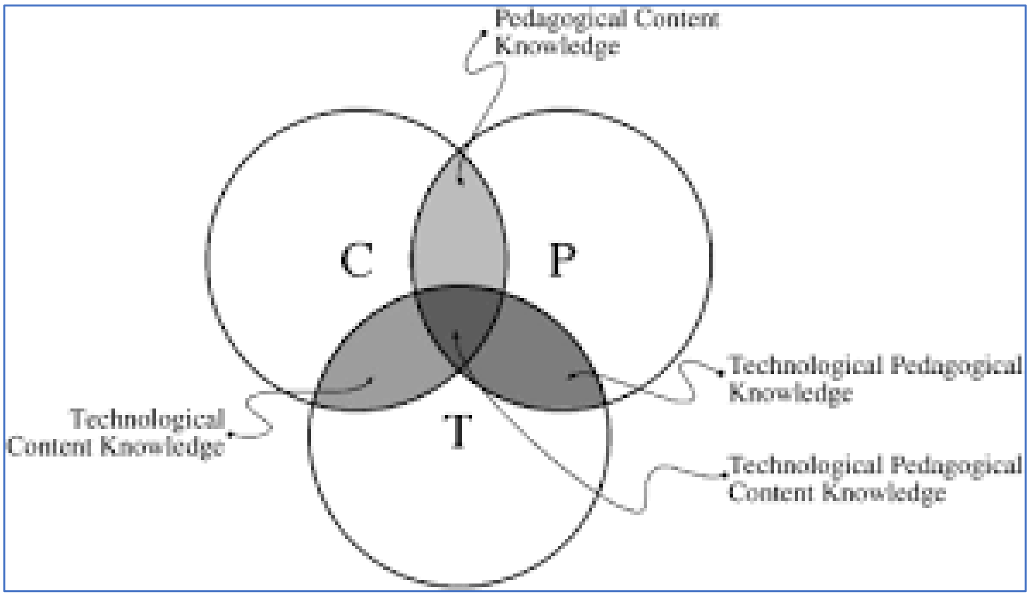


Figure 1:Technological Pedagogical Content Knowledge (sourced from Mishra & Koehler, 2006)

Content Knowledge refers to the knowledge of the subject matter (CK) to be taught. The teacher knows the subject they are teaching: all concepts, laws, principles, and theories that make up that subject (Shulman, 1987; Mishra & Koehler, 2006). The teacher must be knowledgeable other in the quest to have learners know and understand the subject matter. In the case of this study, CK refers to subject matter the teacher educators chose to teach through practical work, meaning the scientific concepts driven through practical work for students' understanding, for assessment or evaluation to also be possible.

Pedagogical knowledge is described as unique knowledge teachers must have to successfully transform and transmit the subject matter and make it accessible to the learners. PK includes knowledge of the learner's background, classroom management, lesson plan developments, and the subject's representation for effective learning. "Pedagogical knowledge (PK) is deep knowledge about the processes and practices or methods of teaching and learning and how it encompasses, among other things, overall educational purposes, values, and aims" (Mishra & Koehler, 2006, p. 1026). For this study, PK refers to how the teacher educators presented the scientific concepts under investigation with the knowledge of students' learning context ranging from situation or context that warranted the shift to the online platforms, students' situation or context in these unprecedented times, geographical locations, digital divides to just mention a few and the knowledge still of what the physics course requires of student teachers to learn practical work and through practical work for assessment/evaluation purposes. PK also speak to the teacher educators' knowledge why student teachers have to learn practical work beyond learning content of the practical work.

Technological knowledge is the knowledge of all the technological applications, equipment, hardware, and software to help meet educational objectives. "Technology knowledge (TK) is knowledge about standard technologies, such as books, chalk and blackboard, and more advanced technologies, such as the Internet and video and this also include the skills required to operate particular technologies" (Mishra & Koehler 2006, p. 1027). For this study understanding teaching practical work and through practical work in physics teacher education, TK refers to how the teacher educators take into cognisant the various technologies ranging from standard to digital technologies when designing and implementing the chosen practical activities for students and also how the knowledge of all these was integrated for learning to take place.

Pedagogical content knowledge (PCK) integrates both pedagogical and content knowledge, where the knowledge of specific teaching methods, strategies, and practices is considered for the specific content to be taught. Shulman (1987) argues that these two types of knowledge in teaching cannot be treated in isolation. They must be blended. "PCK includes knowing what teaching approaches fit the content, and likewise, knowing how elements of the content can be arranged for better teaching" (Mishra & Koehler, 2006, p. 1027).

Technological Content Knowledge speaks to how the various technologies can be used to represent the specific subject matter. It relates the technology to the subject matter taught. For instance, in science, there is an introduction of various apparatus that impact the teaching of certain content, that is, various thermometers used during an experiment do inform the understanding and knowing temperature reading, and it also becomes a different story with computer simulations as there are no physical apparatus. It also speaks to introducing various models via technologies to represent a set concept.

Technological Pedagogical Knowledge implies the relationship between the special knowledge of teachers about teaching strategies, teaching methods and the technological aids that come into changing teaching settings, either to the curriculum planning and design or the teaching practices altogether.

Technological Pedagogical Content Knowledge then brings together all three knowledge components and their interconnectedness and intertwines them. According to Mishra and Koehler (2006), TPCK knowledge is different from disciplinary or technology expert, "it is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones" (p. 1029). And this study reveals how unforeseen online learning brings out this knowledge component in science teacher training programmes, especially for a field that is famously known to happen in a laboratory with designated equipment.

Above, I have presented TPACK and its component as explained in literature for full comprehension of what the theoretical framework encompasses and what it implies for teachers teaching to incorporate technological knowledge in their practices and strategies. It is however, important to relay that this study did not use TPACK to verify, check, confirm or even conclude for integration of technology hence not each and every component is used as pre-conceptualised themes for analysis. The TPACK as theoretical framework for teaching for the 21st century education and as advocated for by the DBE (2020) in the Professional Development Framework for Digital Learning (PDFDL) was used broadly as knowledge base or lens to understand how digital technologies both in strategy and in practice formed part of and how they influenced teaching of practical work in the remote learning context.

3.3. Sociocultural Theory's Zone of Proximal Development

The Zone of Proximal Development (ZPD) is a knowledge component in Vygotsky's sociocultural theory of cognitive development through learning. The Zone of Proximal Development is the middle layer in a development sphere where learning occurs with assistance from other people or other tools. The ZPD is surrounded by two layers, also depicting development zones. The inner zone represents what students already know and what they can do on their own without the assistance of others. They are most comfortable with that, and the outer layers represent what the students do not know or cannot do at all.

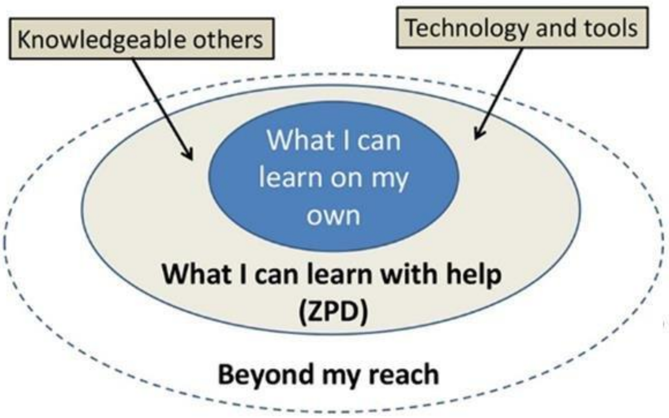


Figure 2: Zone of Proximal Development Model (Adapted from McLeod, 2018)

ZDP is one of the main knowledge components in Sociocultural theory. We are presented with two other knowledge sets, the use of tools, symbols and language by humans and Social Interactions in a cultural and historical development for the internalisation of knowledge (Mahn, 1999). Social interactions and the use of tools and symbols, according to Vygotsky, are crucial in cognitive development processes, they help facilitate higher order thinking skills and development either through individual experiences or social interactions with others learning is mediated through use of tools and semeiotics (Vygotsky, 1978; Allman & Pinnegar, 2020).

Though the knowledge components in sociocultural theory are mostly spoken to separately or treated separately, ZPD and scaffolding are mostly paired together to address the teachers' intervention to ensure learning has occurred. This study, however, embeds the use of tools or human intervention within the ZDP, where learning is mediated through collaboration with fellow students or teacher educators' guidance and various tools. Student teachers in the Zone of Learning and experiencing practical work in their preparation program to become science teachers are guided by humans or other sources. As such, it is important to understand how the different resources mediate learning for students' teachers to engage and experience physics practical work at the level they need to (Penuel & Wertsch, 1995; Mahn, 1999; Kalina & Powell, 2009).

In this study, I investigated how teaching and learning of practical work through practical work is planned, designed, implemented, and learned in a digital technology driven learning environment. I investigated how the students' teachers developed their knowledge of practical work as prospective science teachers from the practical work activities teacher educators planned, designed and implemented for their development. The student teachers' development is explained through their overall experiences engaging with practical work. The ZPD concept in sociocultural theory served as an appropriate lens of analysis in this study because practical work in science education also speaks to students getting hands-on with science concepts. This translates to using designated tools or equipment and practically using your hands with the tools to learn scientific knowledge, skills and processes (Millar, 2008). The knowledgeable other than facilitates these activities through appropriate measures and with set learning goals or objectives. The learning of practical work also occurs in a community setting where it is made of physical science students who want to be science teachers. The design and the facilitation measures of practical work refer to chosen teaching strategies, methods and approaches, which are analysed through the TPCK framework looking specifically at the teacher educators' choice of practical work they designed and its implementation altogether.

Additionally, the sociocultural theory as a learning theory is not sensitive to age groups like Piaget's theory of cognitive development, where cognitive development is explained through stages classified according to age. The sociocultural theory also does not limit the kind of tools, language or symbols, meaning it can be applied in multiple disciplines over time with whatever changes comes with an era. "The specifically human use of tools is thus realized, going beyond the more limited use of tools possible among the higher animals" (Vygotsky, 1978, p. 24). The ZPD concept allowed a better analysis and understanding of student teachers' development of physics practical work knowledge from their experiences with the practical work they engaged with.

Chapter 4: Research Methodology

4.1. Introduction

This chapter describes the research methodology undertaken in this study. In social science, research is understood to be a systematic approach to uncovering the realities of social contexts as humans experience them. It enables the researcher to unearth and understand social occurrences, confirming or refuting what is known with evidence (Lawal, 2019). In agreement with Bhattacherjee (2012) and Lawal (2019), I believe research is a non-straight-cut process to unearth social realities involving interactions between ideas and evidence. This understanding is influenced by the tedious process of having to understand the realities of the phenomenon as per other scholars locally and internationally, to establish the context and the participants to generate the data to support and triangulate the ideas by either confirming or refuting or creating knowledge. The first section describes the research paradigm that was used in this study, which is linked with the worldviews informing the researcher's approach and design to this research. The paradigm is then followed by a research approach, research design, data collection methods used to answer the research questions and ultimately, the data analysis approach. The chapter concludes by discussing the ethical procedures followed with data collection.

4.2. Research paradigm

Research paradigms present the epistemological and ontological standpoint of the research study, bringing forth the philosophical understanding of the phenomena, understudy and viewpoint of reality from which that study is approached (Fazliogullari, 2012). Echoing Kivunja and Kuyini (2017) I view paradigm as a way of viewing the world The worldview of the researcher may be influenced by their experiences of the world, their beliefs and principles to approach their own study.

There are three main research paradigms in social science research: Positivism, Interpretivism and Critical theory (Henning, 2004; Mc Millan, 2014) And this study was informed by the Interpretivism paradigm. Before engaging with this paradigm, I would like to explain positivism and critical theory, and why they were irrelevant to this study. The positivism paradigm bases its epistemology and ontology on what is observable. Epistemology refers to theoretical underpinning of the paradigm, that is what the paradigm knows as knowledge, or how knowledge is justified and ontology refers to contextual or reference frame under which the paradigm stands, that is what counts as reality (Ejnavarzala, 2019). Positivist subscribes to reality being objective, as something that is observation (Creswell, 2013) and it was not suitable for this study because it views human experiences, beliefs and behaviour as something that can be predicted, hypothesised, and tested through observations. The critical paradigm was then introduced to relate power and political influences on social realities to bring about societal liberation (Callaghan, 2016). Critical theory was not fit for this study because this study is not aiming to criticise the incorporation of practical work in teaching and learning science through political or social injustice lens, even though education is a social entity. Finally, the interpretivism paradigm presents the reality of the truth as one interprets or describes it to be. It says that reality is subjective (Alharahsheh & Pius, 2020).

Interpretivism was the appropriate paradigm for this case study. Interpretivism seeks understanding and interpreting human behaviour/actions from their natural setting. This study aimed to explore and understand how teacher educators designed, planned and implemented physics practical work, and how the preservice teacher learned the implemented physics practical work and also how they both experienced working with the designed physics practical work. Interpretivism allowed for each participant's story or viewpoint to be respected and accounted for as presented. Interpretivism allowed me to gain insights into the teaching and learning of science practical work and teaching and learning science through practical work, appreciating each individual's experiences of the processes and the factors affecting the processes in the online learning context. Creswell and Tashakkori (2007) states that interpretivist researchers tend to gain an in-depth understanding of the phenomenon and appreciate the complexities of its context to avoid generalisation or imposing a reality on the phenomena. Interpretivism allows the story to flow as told by participants and what I, as the researcher, make of it to present the diversity within a common story that is not so same after all.

Through the interprevist lens I was able to understand teacher educators and preservice teachers' experiences of working with the designed and implemented practical work under the remote learning. Taking into consideration each of the eight individuals' unique experiences and their narrative of the experiences. With each individuals' unique experience presented in chapter 5, I was able to in chapter 6 compare and contrast reported experiences where possible within the sample of this study and with what has already been written in literature in similar studies without making generalisations to any population. Each teacher educators and preservice teachers' experiences are reflected as they narrated and interpreted in my perspective as per my own lived experiences with practical work and my own views and understanding of the science practical work literature work I have reviewed from other scholars.

4.3. Research approach

There are three types of research approaches in social sciences research, quantitative, qualitative, and mixed-method approaches. The quantitative approach is more aligned with the positivist paradigm, it bases it processes on objective reality (Creswell et. al., 2003). The quantitative research approach focuses on objectively quantifying reality where the researcher has little said on the collected data. It is based on numerical and statistical data to measure reality, where mostly surveys are one of the ways of collecting data (Williams, 2007). For these reasons, this approach was not appropriate for this study because this study was an exploratory study. The other approach is the mixed methods approach considers the objective and subjective reality of the phenomenon under study, the mixed method approach mixes the qualitative and the quantitative approach. It was not relevant for this study because the study only wanted to understand the phenomenon without quantifying the findings to generalise. Lastly, the qualitative approach is more aligned with the interpretivism and critical theory paradigm as it portrays the subjective meaning of reality (Silverman, 2020). It allows a researcher to understand people's experiences, perceptions and meaning-making in-depth, which can be an individual or a group's meaning-making of reality (Creswell, 2009). The mixed methods approach combines both the qualitative and the quantitative approach (Creswell, 2009).

This study followed the qualitative approach because it allowed the inquiry to be subjective. Participants' unique perspectives were sought and considered alongside document analysis to understand the phenomenon under study better. The study sought to understand the kind of practical work conducted, factors that affected the process of engaging in the practical work and the experiences of each of the participants with the practical work. Three students, three lab demonstrators, one lecturer and one consultant were interviewed, I appreciated each participants' perspective of reality with a consideration of their unique context. So, the qualitative approach was appropriate for the researcher to appreciate each story told by the documents and interviewees so to describe, interpret, and narrate in detail the realities of the phenomenon as viewed and experienced by the participants in their context and also with reference to their reasoning in relation to the phenomenon (Creswell, 2009; Njie & Asimiran, 2014; Ezer & Aksut, 2021). In relation to this qualitative research approach, the following section focuses on the design of this study.

4.4. Research design

Research design is defined as a research plan involving the intersection of philosophy, a procedure to be followed in inquiry and specific methods (Creswell, 2009; Babbie & Mouton, 2007). Creswell (2013) presents five designs in qualitative research, i.e., Ethnography, Grounded theory, Narrative research, Phenomenological and cases study. This study used a case study design because it allows for an in-depth understanding of the case and its contextual settings (Creswell, 2013). Yin (2018) describes a case study as an empirical inquiry investigating a contemporary phenomenon in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident (p. 15). And according to Stake (1995), a case study research method "is the study of the particularity and complexities of a single case, coming to understand its activities within important circumstances" (p. xi). A case in this study refers to the teaching and learning of practical work, factors affecting and the experiences thereof in science teacher education programme during remote learning conditions as a phenomenon.

Moreover, it is important to note that there are various case study approaches. Njie and Asimiran (2014) speak of a collective case study, where multiple cases are explored equally in detail to understand a phenomenon. Stake (1995) brings in the perspective of a single case study, and that is studying a single case to understand a set phenomenon, particularly in a certain situation and context. Stakes further differentiate the single case as being intrinsic or instrumental, where the former aims to generalise to a similar case, and the latter aims to unearth and learn greatly about a particular case and not to generalise. A single instrumental case study approach was deployed in this study. As described in section 4.3 above, this study aimed to understand the complexities and particularity of the teaching and learning of practical work in science teacher education during remote learning conditions as it occurs in its natural setting without any intervention or manipulation. The year of study (3rd year) and the particular university were not necessarily major factors. As such, they were not cases but the context within which the case occurred, as Yin (2018) suggested.

In this case, teaching and learning practical work, factors affecting and the experiences thereof, were studied in one school of education in a South African university, where course documents were engaged and teacher educators and student teachers in a single year of study were interviewed to fully understand the process undertaken in this one case. The case was not the university in particular, but the case was the teaching and learning approach to practical work, factors affecting the teaching and learning of practical work and how both teacher educators and student teachers experienced it. The case specifically speaks to the design, facilitation and learning of practical work in its broad sense to understand how science preservice teachers are engaged in practical work in preparation for their teaching especially in the current times. Even though a case study may allow for formulating a generalisation about a phenomenon for different cases, this case proved to be a poor basis for generalisation, as alluded to in Stake (1995). The case was unique in its planning, implementation and how it is experienced even though most schools of education across the South African Institutions of Higher Learning were faced with similar teaching and learning conditions. It is also different to other years of study within the same school of education and university. This is the results of different individuals involved in the course, their context, and their varied perspective about the reality of the physics practical work that they engaged in.

4.5. Data collection methods

Data collection methods are research tools used and steps or processes followed by researchers to generate data on the carried study. They include interviews, observations, focus groups, surveys, document analysis, audio analysis, and video analysis. Creswell (2013) states that data collection is more than the ways of collecting data, mentioned above. It is the process of gaining permission, and powerful sampling strategies that will yield the appropriate and needed data, having well-defined means of recording and storing the data either through digital means or through paper and anticipating the ethical implications of each step one takes during the inquiry. Data generation methods speak to the ways of collecting and managing. In this case study data collection was through document analysis and semi-structured interviews, which are explained in detail below.

4.5.1. Document analysis(review)

Document analysis refers to the process of sourcing data from a varied formatted document of text presenting a set phenomenon for interpretation by the researcher (Bowen, 2009). Owen (2014) suggests three types of document analysis to be undertaken in qualitative research: (a). Public reports, the official documents reflecting an institution's ongoing activities, can be course manuals, students' transcripts, policy documents etc.; (b). Personal documents that reflect individual actions, journal entries, notebooks, emails, WhatsApp chats etc., and (c). Physical evidence. This study explored public reports in the forms of practical work manual (practical work guides), for the year three physics component in physical science teacher education. The practical work manual was used to answer the first sub-question on the nature of practical work taught and learnt in the 3rd year physics teacher education course. Unlike other documents used in the course (course outline, textbooks, formative reports by the consultant etc), the manual was designed for the physics practical work with specific pedagogical instructions highlighting what needs to be learned (concepts and content to be learned), what need to be done and how to do it (procedure) and resources needed for the practical activities (apparatus/materials), the manual also reflected questions that students had to respond to. The practical manual reveals the nature of practical work designed, implemented, facilitated and learned.

Data was sourced from the practical work manual (See appendix K) integral to answering the first research sub-question: What is the nature of practical work engaged in the Physics teacher education course during remote teaching and learning mode? The practical work manuals were meant to reveal the nature of practical work that the teacher educators designed and implemented for preservice teachers to engage in for their 3rd year of study. Table 1 below list the analysed documents.

Table 1: Summary of analysed documents

Name of document	Description of the document
PM01	Practical 1 Manual- Measurements and Hooke's Law
PM02	Practical 2 Manual- Simple Harmonic Motion
PM03	Practical 3 Manual- Wave Model

4.5.2. Interviews

Interviews are key to many qualitative research methodologies that can yield a rich and detailed understanding of the participant's views and experiences (Dilley, 2004; Majid, Othman, Mohamad, Lim., & Yusof, 2017). They are conversations initiated by the interviewer to source out participant's perceptions, feelings and experiences about the phenomenon (Aksu, 2009). There are three types of interviews which researchers can use to collect qualitative data, namely structured, unstructured, and semi-structured interviews. The structured interviews are also referred to as closed quantitative interviews, are in the form of questionnaires with strictly close-ended questions where responses are pre-conceptualised, and they are generally comparable. These are mostly used in quantitative research (Cohen et al., 2007). The unstructured interview is open-ended without a particular guided structure, and quite difficult to narrow down the discussion to a set phenomenon in a particular case. The responses are generally varied across the respondent, thus making it difficult to compare (Cohen et al., 2007;

Kabir, 2016). The two defined types were not suitable for this case study. Semi-structured interviews, on the other hand, are somewhat structured and guided yet not close-ended but within the scope of the phenomenon allowing a researcher to ask direct questions that allow the participants to express themselves and be open to probing on their responses (Aksu, 2009, Kabir, 2016). Semi-structured interviews are interviews with set or leading questions, which also allow participants a chance to elaborate on their answers and give examples. They feature open-ended questions, which does not limit the participants' expansion of their responses (Aksu, 2009, Kabir, 2016). This study used semi-structured interviews to source data from the selected participants. Eight (8) people were interviewed together, where three of them were student teachers, three were Lab demonstrators (Lab demis) who are also tutors, a consultant and the course instructor/Lecturer. These are grouped into stakeholders to categorise them as per their roles in the course, the student teachers for learning practical work, Teacher educators are further divided into Lab demis, who were primarily responsible for the facilitation of practical work and the Consultant, together with the lecturer, who were responsible for the design of the practical work manual.

Three different research interview guides for the three interviewed stakeholders were generated and submitted to the ethics committee before I administered the interviews with each participant. The interview guides played an important role in ensuring that each participant is asked relevant questions for rich data that helped answer the asked research questions. The interviews were primarily meant to first triangulate the data gathered from the practical work manual, that is to find out the nature of practical work that students really engaged on, second to find out the experiences of designing, implementing and engaging with the practical work under the remote learning conditions. The teacher educators' responses also helped with triangulating the preservice teachers' responses to the questions of experiences and factors affecting the teaching and learning of physics practical work and vice versa.

The interviews were scheduled with each participant separately through emails prior administration, and the schedule information included a written brief email text introducing the researcher accompanied by the information sheet and the consent form, which had to be signed and returned prior to the actual interview could be administered. The interview was administered through Ms Teams, with a unique meeting link sent to each participant prior to the meeting date. Before starting with the interview questions, the researcher asked to read the brief introduction of the study to allow the respondent time and space to ask questions of clarity about the study before commencing. Respondents were also asked to give verbal consent and permission to also record the interview. During the interview, the guiding questions were extended or altered depending on the participant's responses to greatly understand the respondent's experiences and views on the inquired phenomenon. Before concluding the interview, the respondents were also asked to ask questions or give some more comments to ensure that respondents understood and could add to the study things that the researcher may have missed with guided questions. The recorded interview conversation was transcribed using the Ms Word dictate option and cleaned by the researcher afterwards. Table 2 below present the interview schedule with the participants (See appendix G-J)

Table 2: Summary of the interview schedule

Participants' Code entry name	Pseudonyms	Occupation	Duration of interview
TEL01	Baloyi	Lecturer	1h1
TEC01	Nelly	Consultant	42min & 1hr (*2)
TEMLD01	Maggy	Mark lab demi	42min
TEMLD02	Bheki	Marking lab demi	1hr22min
TENMLD01	Kaizer	Non-marking lab demi	50min
ST01	Dima	Student/preservice teacher	1hr30
ST02	Palesa	Student/ preservice teacher	40min
ST03	Zwai	Student/preservice teacher	1hr1min

The participants' real names are not reflected in the table, and the pseudonyms and code entry names are given to each participant. The pseudonyms are used to hide the real identity names of the participants. The names though may suggest the gender of the participants, they were loosely allocated to participants without considering the gender. Therefore, a name may reflect a female when it is not necessarily the case that they are female. Other than hiding the identity of the participants, the names are loosely allocated because gender was not a factor in this study. The code entry names, on the other hand, reflect the occupation of each participant to validify responses with regards to what they represent as they respond. The code entry names are used for reporting in chapter 5. Of notice in the summary table above is the interview with the consultant, which happened on two occasions. The first interview was rather disturbed by an unforeseen circumstance which called for a reschedule to continue the interview. The continuation was an easy process as the interview was previously recorded, so it was easy to recap on the previous conversation to allow conversation flow in the second conversation.

There are two interview recordings which were transcribed into one document for analysis purposes.

4.6. Ethical considerations

As guided by the university non-medical research protocol, research study information sheet, interview guides, consent letter and permission letters were drawn and submitted for ethical clearance certificate application which were corrected and were passed through by the non-medical ethics committee. The above documents upon confirmation by the ethics committee were then sent through to the university registrar, the head of school, and head of science division where data was collected for approval and signing. This permission process was confirmed with the University Non-medical research Ethics clearance certificate with a protocol number granted to continue to the research site for data collection (See appendix A).

The permission procedure with the university, school and division management was followed by sending the information sheet to the participants. The research information sheet was first shared with the lecturer, who then introduced the course and all the stakeholders in it. The lecturer supplied the course documents for analysis introduced me to the preservice teachers and, the tutors/lab demis and the consultant in the course, who were then provided with the information sheet. The lecturer then supplied an anonymised mark sheet for preservice teachers' practical activities, which played an integral role in identifying the groups' interviewees. Initially, a sample of six preservice teachers was selected for participation and as recommended by the lecturer for rich data that will allow for an in-depth understanding of the studied phenomenon. However, only three preservice teachers replied to the request and consented to be interviewed. For participation in the study, all the three preservice teachers' participants were interviewed upon signing of consent letters. All participants agreed to the stated conditions of the consent letter.

The data management processes included anonymisation of data and storage thereof the data. The documents were anonymised not to reflect the university name, the academic year, and the names of course presenters. The interviews were transcribed, and the transcripts were all given pseudonyms and code entry names as a means to anonymise and protect participants' identity throughout data collection, analysis and report writing. Though the teacher educators may know who made part of the participants in this study due to the small number in their team, the preservice teachers would, however, not be able to easily identify their groups' participants, as there are 100 of preservice teacher all together in the chosen population. The only person who may be able to identify the preservice teachers' participants may be the lecturer who helped with shortlisting the groups' interviewees and a person who has had engagements with the students about their experience during the sessions. All the raw data and transcribed data were shared with supervisors for verification through google drive, which is protected with a password, and the account is administered by the university.

4.7. Research sampling and participants

Research is conducted to answer a set of questions arising from an identified problem. As stated above, one main question is asked, and three sub-questions were further formulated to answer the main question of this study. Two modes of resources are sourced for data to answer these questions, documents analysis and interviews (human participants). While in a case there could be a lot more documents and a population to gather data from, only relevant documents and appropriate number of participants were chosen to answer the research questions. Taherdoost (2016) states that a sample need to be selected as it is doubtful that a researcher can collect data from the whole case to answer research questions.

"Sampling is a process of selecting subjects to participate in a research investigation because they provide information considered relevant to the research problem" (Oppong, 2013, p. 203). The research sample refers to a particular individual or group from which the required information is sourced to answer one or a set of research questions. The group or individuals may be part of a larger population, sometimes referred to as representatives of the whole population in a case. In a qualitative study, especially a case study, a sampling technique is always applied to manage the risks in terms of data size, contextual issues, time constraints and other limitations that may arise. Sampling is also done so that the researcher may be able to get as much in-depth qualitative data from the selected participants. For a researcher to collect the required data they need to select a good sample, they must be well aware of the scope of their study, know the targeted population, and understand the sample frame from which to select the population representatives and the research sampling technique (Taherdoost, 2016). Even though the studied case had a population of about 100 people, only 8 individuals participated in the interviews. The population respectively used varied documents (course manuals, textbook(s), and practical manuals) to teach and learn practical work. However, only practical work manuals were used to source data, and were also triangulated with the participants' responses to the interview questions.

4.7.1. Selection of Participants

The sampling methods in research are often addressed when the data collection method followed involves a population. In this case, it is much more relevant for the interview data collection methods used. The target population refers to the people or a community in a set case which data is to be collected from (Taherdoost, 2016). The target population, in this case study, refers to all the individuals who are involved in the processes of teaching and learning practical work of physics practical work in the year three physical science teacher education course in the chosen South African university. And this case has a population of over 100 people, made up 4 different stakeholder groups. The sample was chosen from each [1]stakeholder group for the interview data collection method. Acharya, Prakash, Saxena, and Nigam (2013) define a sample "as a subset of a population which serves as a representative of a larger population" (p. 330). From a population of over a hundred people, about 100 students, six tutors/lab demonstrators, one lecturer and one practical work consultant, only eight individuals participated in the interviews.

The non-probable purposive sampling technique was applied in selecting the 8 participants. Acharya et al. (2013) define non-probable purposive sampling as a method where the subject is selected at the convenience of the investigator, which also speaks to researcher biases. The non-probable purposive sample was used because the study aimed to unearth the realities of teaching and learning of practical work as the participants experienced it without also generalising it to the whole population or even to the 3rd year physics education for teachers' course in a South African University. So, while the teacher educators were in a better position to tell their experience of teaching practical work. The preservice teachers had to have engaged with all three practical manuals and have submitted for feedback as the mark sheets were used to identify the preservice teachers' participants who had the feedback for all three submitted practical work activities. These are preservice teachers' who have proven to have engaged with practical work as per the mark sheet, and it is worth mentioning that the aim of the mark sheet

[1] Stakeholder groups refers to the different classification of the people participating in the course. In this case it includes the lecturer, the practical work consultant, the tutors/lab demonstrators, and the students. The stakeholder groups in research terms refers to the sample frame from which data was collected from.

was really not to measure their performance as such but to diversity the experience as I believe the marks tell a story beyond just performance.

As stated, sampling in a qualitative study is not qualified by the need to generalise, as such the findings from the collection cannot be generalised beyond the sample (Higginbottom, 2004; Acharya et al., 2013). Dhivyadeepa (2015) argue that "sampling in educational research is generally conducted to permit the detailed study, rather than the whole, of the population" (2015, p. 3). The eight selected participants were appropriate and enough to permit me to draw enough detailed data to work with in answering the set research questions.

4.7.2. Teacher educators

The selection was obvious for the lecturer [2](TEL01) and the consultant (TEC01) as it was just them who were responsible for the course. So, I interviewed both to understand the design and roll-out plan or implementation plan of the designed practical work and also their experiences with the design and implementation processes that unfolded. For other stakeholders where a handful was, a sampling technique had to be applied. Out of six lab demonstrators, only three were interviewed (TEMLD01, TEMLD02, TENMLD01), with the information that the six lab demis work in pairs, each responsible for each class made up of about 33 students. So, each pair was represented by one lab demis who was selected based on their duty and availability. Initially, the sample had to be made up of tutors who were also responsible for marking and giving students feedback based on the practical work script they submitted. However, based on availability, only two tutors from two pairs were a perfect fit for that selection criterion, and from the other pair, the marking tutor was not available, and the non-marking tutor was interviewed.

4.7.3. Preservice teachers

The selection criteria for the preservice teachers' sample frame were informed by their participation throughout the course lecture sessions and practical work sessions, their marks (and not performance, the students had to have a mark for each practical activity they had to

[2] The TEL01, TEC01, TEMLD01, TEM02, TENM01 are codes generated to anonymise and protect the identity of the participants (while they are also given pseudonyms the codes are used for reporting as they also symbolise their occupation and roles in the teaching and learning of practical work. The different letters in the code are broken down as follows TEL01- Teacher Educator who is a Lecturer 01, TEC01-Teacher Educator who plays a consultant role, TEMLD01- Teacher Educator -1 of 2 marking lab demonstrators, TEMLD02- Teacher Educator-2 of 2 marking lab demonstrators, TENMLD01- Teacher Educator who is a non-marking lab demonstrator. They are all classified teacher educators as they all are in one way or the other involved in the teaching of practical work.

participate into addressing the participation criteria for the practical work sessions) as per the marked sheet presented by the lecturer. Each class (out of three classes) had to be represented and finally on their availability. The study initially targeted six preservice teachers for interviews, two from each class. However, only three out of the six responded positively to the interview invitation. The high, middle and low marks categorisation also allowed for the selection of two preservice teachers in each category. Three preservice teachers' population representatives had one [3](ST01) with the highest mark (94%) and who was also a class representative, another (ST03) had a high mark (86%), and another (ST02) had a low mark 13%) though not lowest. Three other preservice teachers did not respond to the invitation. Two of the preservice teachers had marks categorised as the middle (ranging between (50-60%), and one student in the low marks' category (ranging between 0-45%). Preservice teachers with marks ranging between 0-10% had no marks for the practical activities or they had missing marks for certain practical work activities which speak to their limited participation in the course meaning they were not suitable for rich data collection. Figure 3 below presents students grades scores used for sampling.

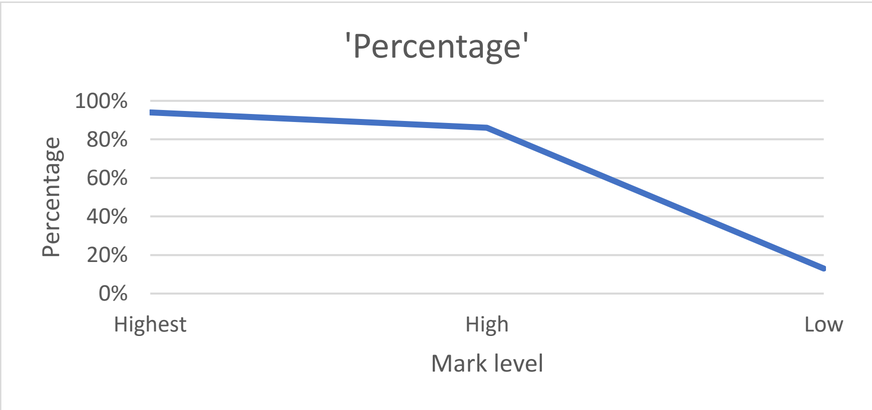


Figure 3: Sampling of Student participants- average grading across the three practical tasks.

Even though not all preservice teachers responded to the invitation, each lab group was represented where the interviewed students were allocated to different pairs of tutors/lab demonstrators. The three students provided data rich enough to respond to the research questions, they all engaged with all the practical activities that they were presented with as they had reflecting marks for each one, so they were able to talk about their experiences with the practical work component of the course and also share the challenges and opportunities

[3] Even though the preservice teachers are given pseudonyms to protect their identity, they are also allocated codes to specify their occupation for reporting. The codes ST stand for student teachers and the numbers representer the number allocated to each interviewed student so that it easier to identify them.

presented by the activities. They were also able to share some recommendations for practical activities they engaged in and the rethinking of practical work in the current era. Suri (2011) argues that purposive sampling yields information-rich data that can lead to an in-depth understanding of the phenomenon under investigation. Their diverse experiences gave light and understanding for the rethinking of practical in the current era of learning.

4.8. Sampling strategy

To proceed with data collection, a research site and a population must be identified and defined to allow for appropriate sampling to answer the formulated research questions. "The researcher thinks of possible research participants, individuals, groups, organisations, or sites as soon as they have formulated the research questions and identified all resources for the study (Devers & Frankel, 2000, p. 264). In this study, a case was selected, and this section presents the context of the case study, as it is important to know and understand the background of the studied case to understand the data holistically as shared by the participants.

4.8.1. The nature of the studied programme

In this case, the 3rd year physical science course was explored as the physics component was the one offered during the time data was collected, looking specifically into the teaching and learning of physics practical work. Practical work in this school is normally conducted in a laboratory where there is a provision of designated apparatus for students to work hands-on within their learning of practical work. Depending on the number of students enrolled in the course, the students are placed in laboratory groups which are also tutorial groups, and they are allocated tutors/lab demonstrators to assist them with the tutorials and practical work during the specified periods, respectively. While both tutorial and practical work sessions happen in the same place, they occur at different times, and both students and tutors meet in the same place at that period. Practical work sessions are allocated three hours, and the time slot is allocated once a week.

However, that was a norm, the program had to be moved to online platforms for teaching and learning to continue as the lockdown regulations were enforced in SA and around the world. This meant rethinking the norm as the laboratory was no longer accessible for practical work, which also meant no access to the usual laboratory designated apparatus. The new teaching and learning process was, however, like the old process in that practical work was allocated a 3-hour slot once a week, laboratory groups were still operational, and lab demonstrators were also made available to still assist students through the online platforms used for the teaching and learning. The students and lab demonstrators had to make themselves available online to engage or participate in practical work activities during the allocated slot.

Table 3: Practical work before and after remote learning in the school of education

Physics 3 teacher education course	**Normal teaching and learning conditions**	**Remote teaching and learning conditions**
Mode of teaching and learning	Contact lessons	Online lessons
Practical Time allocation	3hours a week	3 hours a week
Platform for teaching and learning practical work	Laboratory	Home-based practical work (termed At home practical work by the design team)
Availability of assistance	Yes, tutors/Lab demis onsite	Yes, tutors/lab demis online via WhatsApp

4.8.2. Participants' background information and roles

The teaching and learning process of the physics component was led by one lecturer who works with a team in designing and implementing the practical work session. In the design space, he works with a consultant who has considerable experience in designing science practical work in unfavourable situations in South African secondary schools. The consultant was sought by the division head and physical science course coordinator based on his experience and expertise to assist in designing practical activities in both physics 3 and 4 in the abnormal situation they had to teach under. The lecturer then worked with a group of tutors/lab demonstrators to facilitate the designed practical work sessions. The class had enrolled 100 students who were divided into a group of three and allocated a pair of tutors/lab demonstrator each for the whole year. The lab demonstrators were fully responsible for facilitating practical work under the lecturer's supervision. In a lab group, there were two lab demonstrators who operated as partners in the facilitation of practical work, with one lab demonstrators having the extra duty of marking students' scripts and giving them feedback based on their submissions. Table 4 below summarises the interviewed teacher educators' background information and their experience in their roles.

Table 4: Teacher educators' profile

Participants pseudonyms	**Educational Qualification**	**Work experience with physical sciences practical work**	**Role in the physical science teacher education course**	**Participants entry code**
Baloyi	Bachelor of Education in Physical Sciences, BSc hons in Science Education, MEd in Science Education	6 years of physical science teacher training.	Course instructor/ Lecturer	TEL01
Nelly	BSc in physics, master's in science	Pre-1978 teaching physical sciences in high	Practical work in physics consultant	TEC01

	Curriculum, Post Graduate Certificate in Education	school and then NGO work on various physics practical work projects for ordinary schools		
Maggy	B. Ed, Master's science education, PhD candidate	3years	Marking Demi/tutor	TEMLD01
Bheki	B. Ed honours physical sciences Masters' candidate	10 months	Marking Demi/tutor	TEMLD02
Kaiser	B. Ed 4th year in Physical science and Mathematics education	3 years	Supporting Demi/tutor	TENMLD01

From the Table 4 above, everyone except for 1 of the teacher educators has either a PGCE or B. Ed degree with a postgraduate qualification in physical sciences education. The anomaly, in this case, is Kaiser, who is a supporting lab demonstrator/tutor who is still busy with the B. Ed degree. As a support lab, demi Kaiser is not taking the lead in facilitating practical work; however, support the marking lab demi in the lab they are responsible for.

The learning process of the designed practical work was influenced by various factors, including students' previous experience as far back as high school. Students in the studied programme have different enrolment conditions as the university has undergone a curriculum transition. This factor, however, did not have an impact on sampling as the students engaged in similar content and faced the same requirements for qualifying to enrol in the course. There are students who have the course as a major specialisation, and other students (who are in the old curriculum) have the course as a second major specialisation. Three students out of a hundred participated in the interviews. Two of the students are enrolled in their 3rd year of study and have physical sciences as a major, and one student (ST02) is enrolled in her 4th of study and has physical sciences as a second major. The students who participated in interviews reported different experiences with practical work from their high school days with the physical science subject. ST01, even though her school did not have the appropriate apparatus to carry practical work, she fully engaged in hands-on practical work in her high school since her high school teachers featured practical work in her curriculum coverage. [4]She reports that "*in my school, we had to always improvise as we lacked resources*". ST02, on the other hand had no idea of practical work in science. What she got exposed to in her high school was just abstract teaching of physical science without any practical work being infused in the curriculum

[4] The classification "she" does not reveal the gender of the participants. Even though the students were of different gender, she was used uniformly to refer to all participants as gender was not a determining factor in this study.

coverage. She reports that *"I think my teacher hid practical work from us, and they actually tried their best to have us get beautiful marks, my school was poorly resourced".* ST03 partially engaged with practical work in high school, and this was the case because a certain science tutorial group partnered with their high school to specifically teach them practical work, as their school did not have the resources. The partnership did not happen for long, as she reports, *"we only did practical work on Newton's Laws in grade 11 and that was the last time I saw them".* STO3 also reports that her physical science teacher would always come to the class and read out practical work from the textbook without having them engage hands-on with it as it was part of the curriculum.

During the interview, all three students expressed difficulties with physical laboratory practical work in their first year of the teacher education course when they had to work with sophisticated science laboratory apparatus, which they did not know their names or even how to use. They report that the designated lab demonstrators had to start teaching them the names of the apparatus and then demonstrate how to use them. This, for them, was expressed as a short experience as they had to move online shortly after just opening schools the first semester in their second year of study. And in their first experience of online learning, they had a practical equivalent which comprised of simulations and written practical work scenarios accompanied by a video of the same or similar scenario making their practical work learning for the physical science component of the natural science course. Table 5 summarises the students' background experience with learning physical science and their engagement with practical work in high school, and their enrolment conditions in the programme.

Table 5: Student teachers' profile

Participants name	**High school experience with practical work**	**Physical science as a subject in high school**	**Physical science as a Major subject in university**	**Student teachers' entry codes**
Dima	Full engagement	Grade 10-12 physical science	Specialisation	ST01
Palesa	No engagement	Grade 10-12 physical science	Non- specialisation	ST02
Zwai	Partial engagement	Grade 10-12 physical science	Specialisation	ST03

The students as indicated in Table 5 above, have varied engagements with practical in their learning of science since high school. The degree to which students have engaged with practical work in their FET phase in high school differs amongst the ST01 and ST03, while ST02 have never been exposed to practical work in high school. Their biggest shock came in the first year of the teacher education programme and when ST02 had to go for teaching practice in schools and they had to teach practical work. Though the ST01 and ST03 had encounters with practical work at different levels, their biggest shock in their first was when they had to work with designated physics laboratory apparatus, which they never had a chance to work with in their respective schools. They stated that regardless of the lack of apparatus, their teachers improvised with materials and had an external organisation to the school to have students engage in practical work or read the practical work from the textbook respectively. All these students were taught the under the same physical science curriculum requirements in a South African FET phase, however taught by different physical science teachers and under varied contexts.

4.9. Data analysis

Qualitative research, as described in the data collection section, is text bound and subjective, where the problem or the phenomenon is understood from the participants' perspective (Akinyode & khan, 2018). However, there is due process needed for the perspective to be understood. Ryan (2006) states that data in its raw nature cannot speak for itself, so for it to represent what it is addressing, one must analyse it and produce evidence. The analysis process itself is much more than just findings, but is a bit much of a process of organising, reading through to get familiar with the data, coding, generating themes, and presenting the data for interpretation (Creswell, 2013). In qualitative research, data analysis is generally employed to interpret the data and resulting themes so as to generate a deep and nuanced understanding of the phenomenon under investigation (Lester, Cho and Lochmiller, 2020; Sargeant, 2012). Figure 5 below shows the data analysis spiral adapted from Creswell (2013), which guides the analysis steps followed in this study.

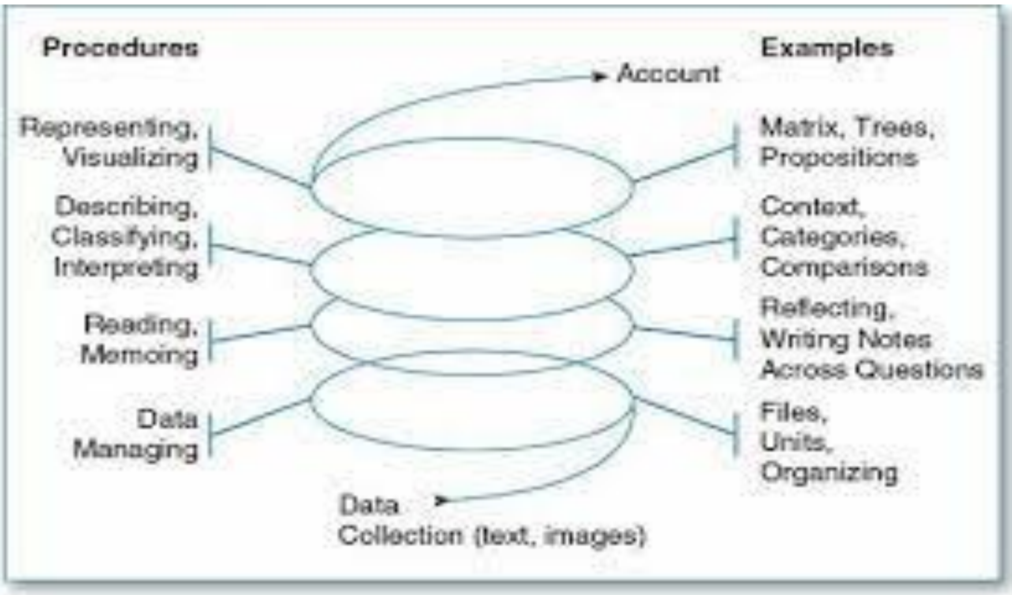


Figure 4: The data analysis spiral (Sourced from Creswell, 2013)

4.9.1. Step 1: Preparing and organising data.

The data analysis process followed in this was guided by [5]Creswell's data analysis spiral. Creswell (2013) states the three strategies for data collection as preparing and organising data, coding and creating themes and then presenting and interpreting data. Preparing and organising data is the first loop of the spiral, which involves managing data. Data organisation was an easy but long process after the data had been collected. This step follows right after data collection, when the raw data has been archived, well arranged, and labelled in folders. I used the Ms Word dictate option to transcribe the recorded Ms Teams interview session with the 8 participants, for which I had to have two devices. One device was playing the recording, and the other was automatically dictating into word text as the recording went on. This process had to happen in a very quiet space so that the dictating device could capture the correct sound. The dictate option does not really capture the words in the recording clearly due to the south African English sound and accent. It also does not have a particular structure in which the transcription can have well-defined paragraphs indicating the alternating speakers, time, or even the most appearing words (key takeaways). I had then to follow through with cleaning the data, where I had to divide the huge Ms Word-generated paragraph into a chunk of paragraphs as per each speaker in the dialogue. The data cleaning and processing was done simultaneously with reading through the data, as I also had to clean up the words. The dictate option is not friendly

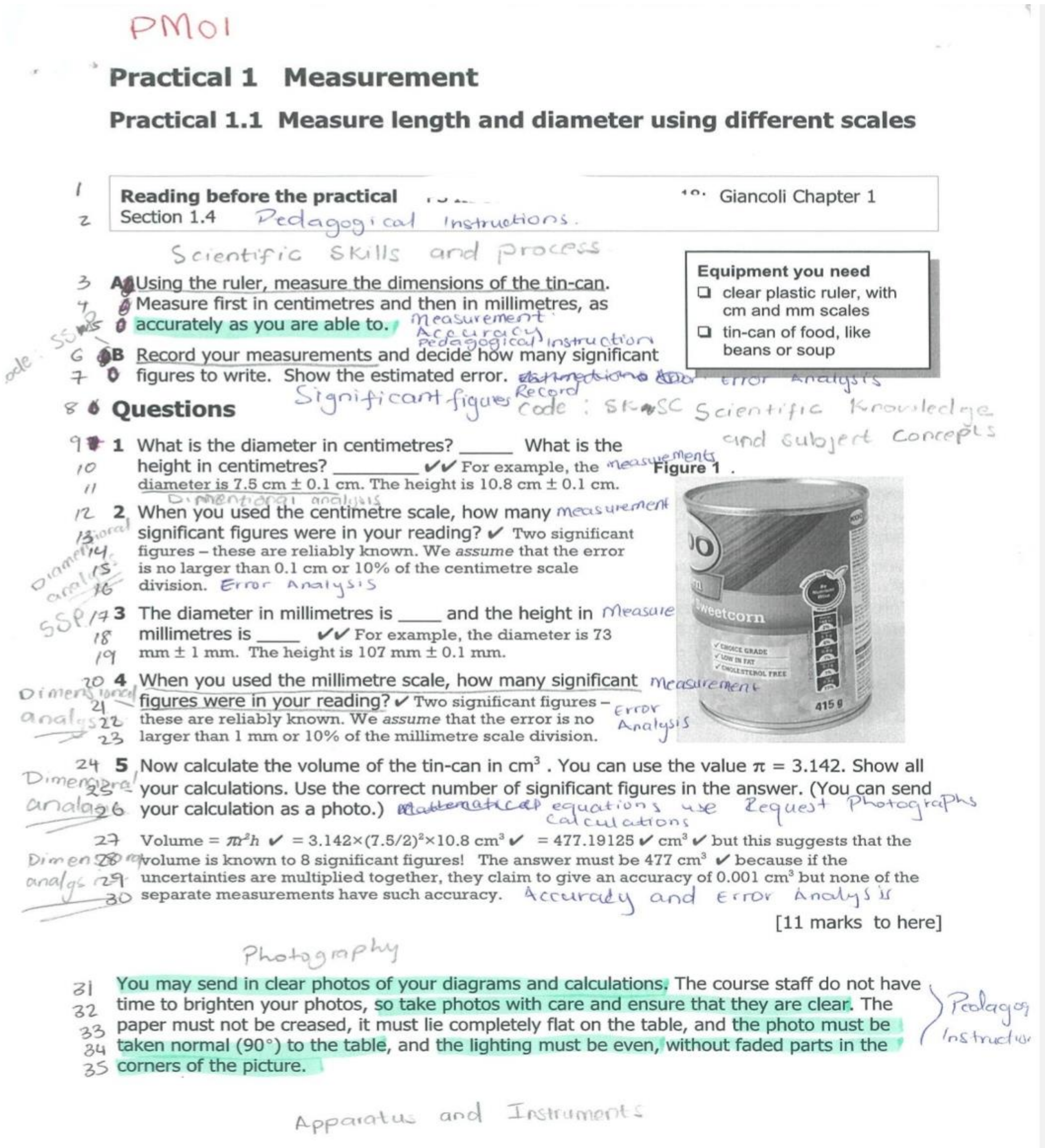
[5] Creswell's data analysis spiral is a diagram created by Creswell to guide the entire process of data analysis. Creswell (2013) state that there are variation of data analysis strategies referring to three different authors Madison (2005), Huberman and Miles (1994) and Wolcott (1994b).

to the English accent the interviewer and interviewee used during the conversation, so certain words were not captured accurately as uttered in the recording. This process took about three weeks to complete in the month of January as soon as all the data was collected in December when the students finished their exams.

The three practical work manuals were already formatted in text and organised in an analysable manner. The pdf format was suitable for analysis. It allowed for one to analyse either the soft copy or a print hard copy as the text format remains in structure with all the photographs/illustrations and links included in the documents. The interview data required to be organised to allow for analysis. Data management and processing had to be completed for easy access the database. Creswell (2013) states that "besides organising files, researchers convert their files to appropriate text units for analysis either by hand or by computer.

4.9.2. Step 2: The actual data analysis step

The analysis step follows through after preparing and organising the data. It is a rigorous step starting with familiarising yourself with a large database and reducing it to comprehensible phrases with evidence in creating new or alternative knowledge about the phenomenon under study. Wong (2008) alludes that "qualitative data analysis entails reading a large number of transcripts looking at similarities or differences, and subsequently finding themes and developing categories" (p. 14). The researcher read through the transcripts or other sources of data and memo through the transcript as they get familiar with the data. Reading and Memoing allow the researcher to get to understand the responses given by participants or the data on the documents, videos, or photographs as per the source's perspective without imposing their own views (Creswell, 2013). The familiarisation process unfolds without predetermining the questions or even considering of theoretical framework or literature. This step of qualitative analysis allows for in-depth understanding with no restriction to predetermined categories or codes (Akinyode & Khan, 2018). The process unfolded with all two data sources, the interview transcripts and the practical work manuals. Where notes were written on the document's margins, and transcripts were highlighted with various colours while scanning through the data without considering any guiding tool. Creswell (2013) refers to the process of writing notes on the margins as memoing, in which memos are described as short phrases that occur to the reader (meaning the researcher). See figure 6 below for an example of memoing as phrase or words are written with pen as I was to highlight some of the important words or draw out specific data out of the practical work manuals. The process was done with all three practical work manuals.



PM01

Practical 1 Measurement

Practical 1.1 Measure length and diameter using different scales

Reading before the practical — Giancoli Chapter 1 Section 1.4

Equipment you need
- clear plastic ruler, with cm and mm scales
- tin-can of food, like beans or soup

A Using the ruler, measure the dimensions of the tin-can. Measure first in centimetres and then in millimetres, as accurately as you are able to.

B Record your measurements and decide how many significant figures to write. Show the estimated error.

Questions

1 What is the diameter in centimetres? _____ What is the height in centimetres? ________ ✔✔ For example, the diameter is 7.5 cm ± 0.1 cm. The height is 10.8 cm ± 0.1 cm.

Figure 1

2 When you used the centimetre scale, how many significant figures were in your reading? ✔ Two significant figures – these are reliably known. We *assume* that the error is no larger than 0.1 cm or 10% of the centimetre scale division.

3 The diameter in millimetres is ____ and the height in millimetres is _____ ✔✔ For example, the diameter is 73 mm ± 1 mm. The height is 107 mm ± 0.1 mm.

4 When you used the millimetre scale, how many significant figures were in your reading? ✔ Two significant figures – these are reliably known. We *assume* that the error is no larger than 1 mm or 10% of the millimetre scale division.

5 Now calculate the volume of the tin-can in cm^3. You can use the value π = 3.142. Show all your calculations. Use the correct number of significant figures in the answer. (You can send your calculation as a photo.)

Volume = $\pi r^2 h$ ✔ = 3.142×(7.5/2)²×10.8 cm³ ✔ = 477.19125 ✔ cm³ ✔ but this suggests that the volume is known to 8 significant figures! The answer must be 477 cm³ ✔ because if the uncertainties are multiplied together, they claim to give an accuracy of 0.001 cm³ but none of the separate measurements have such accuracy.

[11 marks to here]

You may send in clear photos of your diagrams and calculations. The course staff do not have time to brighten your photos, so take photos with care and ensure that they are clear. The paper must not be creased, it must lie completely flat on the table, and the photo must be taken normal (90°) to the table, and the lighting must be even, without faded parts in the corners of the picture.

Figure 5: Sample for memoing of practical work manuals

Upon writing the short phrases, the researcher then moves on to finding similarities or differences within the dataset. Creswell (2013) refers to this process as describing, classifying, and interpreting the data into codes and categories in the spiral. Akinyode and Khan (2018) also state that the qualitative approach includes analysis that allows for interpretation through coding, describing, and translating data as it is naturally occurring instead of the frequency phenomenon. Meaning that statistical accounts are not central, however, meaning is created textually out of what is explained either in writing or in words by the respondents. The essence of qualitative data analysis is not to account for the number of times something has occurred but the understanding of various viewpoints on experiences, perceptions, and feelings. The process of creating descriptions in the dataset is when the researcher gets to understand the data as presented to be able to classify and categorise evidence which can be presented as findings for interpretation and meaning-making about the phenomena.

The researcher describes and classifies data systematically. The approach is also referred to as generating codes or categorising data. Coding or categorisation becomes systematic in the sense that literature or the researcher's view is employed for interpreting the data. Creswell (2013) states that "in creating codes or categories, the researcher builds detailed descriptions, develops themes or dimensions and provides interpretations in light of their views or the perspectives in literature" (p.184). The analysis can be a one-layer or multi-layered process, where codes are grouped together to form categories which can further be grouped into themes, which lead to the last phase of the data analysis spiral. The last phase is where the researcher is able to present and visualise the analysed data. The researcher may present their interpretation of the data in a diagram, table, chart, or image (Creswell, 2013). Depending on what the researcher wants to communicate or rather what the data communicate, the chosen representation will have to communicate accordingly. The comparison data may be presented in a comparison table, a flow or Venn diagram may be used to indicate a relationship, a pyramid or related diagram may be used to indicate hierarchy etc.

The spiral data analysis is a general approach that was used to inform the analysis in this study. This approach can be summarised as a process of learning to teach, where a researcher learns the data as found or collected, make sense of the data, and create new or different lessons in light of their own understanding of the data or in light of relevant literature and teach the data the way they deem fit. The data analysis spiral approach can be aligned with the inductive analysis approach. The inductive analysis is more popular alongside the deductive analysis approach in qualitative research. The deductive and inductive analysis are approaches to analysing qualitative data that allow for coding or categorisation of data data to answer a set of research questions. The deductive analysis works with themes emanating from a framework that would organise the data into core concepts of the theoretical or conceptual framework and the inductive analysis approach work through the data by reading through the data over and over and assigned codes and derived themes and categories that were used to describe the data as guided by the objectives of the study (Bradley et al., 2007; Azungah, 2018).

The spiral approach like the inductive analysis allowed for the researcher to familiarise with the raw data, code the data without reference to the theoretical framework, research questions or literature at first reading of the data. Initial codes were derived from the raw data, then organised into categories with reference to the research questions and general themes were formulated thereafter to make meaning with the help of the literature and the theoretical framework. Unlike the deductive analysis approach were codes are pre-conceptualised with reference to the theoretical framework, the spiral approach used in this study derived codes from the data and use literature and the theoretical framework to make of emerging codes to categorise and thematise the codes. It allows the researcher to move from more specific codes in layers into more general themes. (Creswell, 2013).

The study consulted science practical work-related literature, a learning theory as a conceptual framework and a teaching theory as a theoretical framework. However, they were not central in the analysis in the sense that the data did not have to refute nor confirm what the views in literature and the theoretical framework lenses are saying. The data was not meant to create general statements that would apply to the entire population or even inform policy in the field. The data was analysed in the sense that the case was understood with its own unique features and created a platform for the phenomenon to be explored further beyond the case. The consulted theories were viewing lenses to help interpret, discuss and make meaning of the data. The literature, theoretical and conceptual framework were used to understand the nature of practical work engaged in, the teaching of the designed and implemented practical work and the learning of the practical work respectively. The practical work literature and the TPACK framework was instrumental in helping understand the codes that revealed the nature of practical work engaged in and the teaching of the practical work while both TPACK and ZPD frameworks helped me to make meaning of the codes that revealed the experiences and the factors affecting the teaching and learning of the designed physics practical work for the studied physical science preservice teacher education course.

The aim of this analysis was to answer the research questions as outlined in chapter 1. And data was analysed from two sources, document analysis (3x practical work manuals) and interviews (8x multi-stakeholder interviews). The analytical frameworks for the two data sources followed a similar pattern informed by Creswell’s data analysis spiral approach. The spiral approach allowed me to get familiar with the data first, then take out similar and different phrases relevant to answering the question asked by the study within participants’ responses. I then followed with categorising the phrases into codes and then formulated themes according to my own understanding of both literature and the theoretical lenses outlined in chapter 3. Due to the nature of each data source, the analysis steps were not similar. The document analysis was single layered and straightforward the memoing process was limited to just a single layer due to the self-explanatory data presented in each practical work manual. The initial codes operated as themes or categories, I had to make meaning of the data just as I read through each line. While the interviews followed a long and complex process, where the full spiral approach was followed. The analytical framework used in each data source is presented respectively.

4.9.3. Analytical framework: Document analysis

Practical work manuals represent activities designed and implemented for learning. They serve as a guide for preservice teachers to successfully complete an activity. Teacher educators rolled out a total of three practical activities for a semester. The three practical work manuals (PWM) present a similar way of engaging with the activity, meaning that students had to follow similar processes to complete the activities. The design, structure, and organisation of text in the three manuals is similar. They all drive a scientific idea for students to learn. However, each activity is driving a different central science idea. Millar (2009) states that practical work aims to make links between two domains, the objects and observables domain and the domain of the idea. It is really quite interesting to see what and how the designed activities for the remote learning context aim to teach.

The analysis approach followed or deployed in the practical manual analysis was at most influenced by my understanding of the Practical Activity Analysis Inventory (PAAI) formulated by Millar (2009). Millar (2009) formulated the practical work analysis framework assess and improve its effectiveness. However, the objectives of this study were not to assess the practical work for improved effectiveness but for understanding the nature of design and implementation of the practical for Physical preservice teachers in initial teacher education programme. The case in this study was to understand the design and implementation of the practical work activities, looking deeply into what the teacher educators intended the preservice teachers to know, what they had to do and how they to work with the designed practical work they were intended to engage in. The effectiveness of the activities was not studied as I was not interested in improving the effectiveness of the practical work activities designed and implemented for this case, the analysis was not deep into assessment and evaluation. This study viewed the assessment and evaluation of practical work as a huge task that required its own scope of research to do justice to the process of addressing the effectiveness of practical work in the science teacher education programme. For assessment and evaluation of the practical work for improved effectiveness an intervention study more than an exploratory study is more suitable to measure the effectiveness.

Great focus in the analysis of the practical work manuals was on the objectives and focus of each practical work activity that the preservice teachers had to engage in and the instructional strategies or instruction techniques which are classified as knowledge management strategies as per the code (KMS) that may be visible in text as written in the manuals. The code terms used to interpret the data are defined with reference to the theoretical framework and the various literature on pedagogy or teaching and practical work in Science education research (Shulman, 1987 (PCK); Mishra & Koehler, 2006 (TPACK); Millar & Abraham; Millar, 2008, 2009, 2010). The definitions are not direct quotes from the literature. They were rephrased to suit the characteristics of the analysed data. Some of the analysis codes were taken from the interview data, with definitions given by participants such as the "Kitchen Table Practical Work (KTPW) and Simple accessible material (Sam)". Table 6 below indicates the emerging codes from the analysis of the practical work manuals.

Table 6: Emerging code list and their definition

Codes	**Code name**	**Definition**
TK	Technological Knowledge	Refers to the knowledge student teachers and teacher educators are required to have in using various technological devices or tools to help them teach and follow/understand procedure, processes, and science knowledge respectively.
SK	Science Knowledge	Refers to statements reflecting the understanding of scientific content or concepts that students should either be knowing, or they are intended to know from the activity.
Ps	Practical skills	Refers to the hand on procedural knowledge that students should know and understand to actually do work with the materials as instructed.
Ses	Scientific enquiry skills	Refers to the students' ability to understand the aim of the practical activity to either formulate a hypothesis, the ability to collect relevant and perhaps accurate data, analyse and interpret the data for making conclusions.
KMS	Knowledge Management Strategy	These are instructional or actionable texts or illustrations found in the practical work manuals which direct students on what do, how to do it, what to know and sometimes how to know it.
Sam	Simple accessible materials	Refers to non-scientific materials or apparatus which can be bought in stores or recycled or found in the kitchen counter at home that students must use to conduct their practical activities.
KTPW	Kitchen Table Practical Work	Refers to statements mentioning or specifying the kind of practical activity the students need to conduct, specifying the context under which they will perform the activity.
HoS	History of Science	Refers to a statement reflecting ancient scientific processes to indicate where and how the concept(s) under study originated.
EK	Everyday Knowledge	Refers to statements used to unpack the scientific concept or content; science concepts explained in simple English terms.

Figure 7 below indicate the actual steps taken when analysing the three practical work manuals guided by Creswell's data analysis spiral approach.

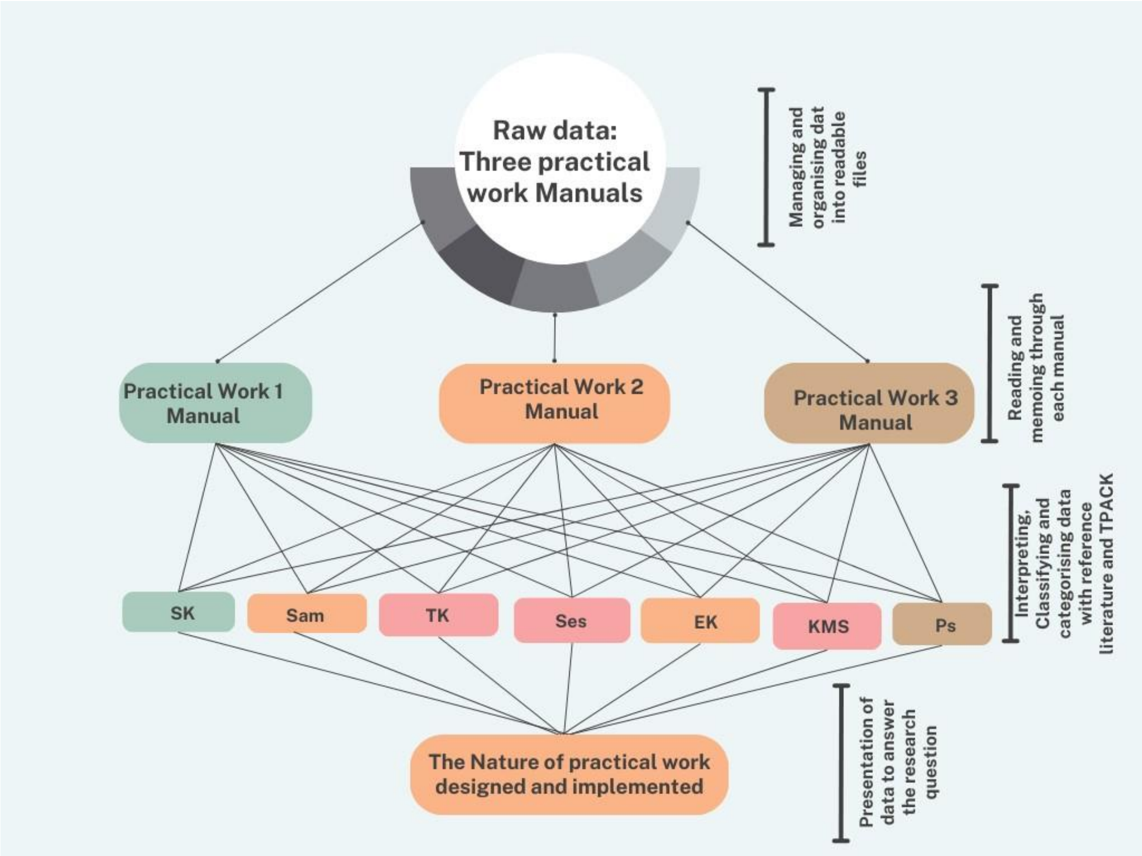


Figure 6: Spiral approach to practical work manual data analysis

As per figure 7 above, practical work manuals represented the raw data that were analysed, by reading and memoing through each manual (refer to figure 6 for a sample of how the process is happened), after reading and memoing each practical manual the data with interpreted and categorised with short codes that were guided by the understanding of literature and the theoretical framework see the categorisation in table 7 below. The analysis of the data is then presented in chapter section 5.2 were the findings and analysis are detailed. Table 7 indicates how the codes were identified and how the data was analysed. Also see appendix L, sampling the coding of practical 2 manual.

Table 7: Practical manual code analysis sample (Practical 1 manual)

Excepts	**Codes/categories**
You may send in clear photos of your diagrams and calculations. The course staff do not have time to brighten your photos, so take photos with care and ensure that they are clear. The paper must not be creased, it must lie completely flat on the table, and the photo must be taken normal (90E) to the table, and the lighting must be even, without faded parts in the corners of the picture.	TK, KMS

Using the ruler, measure the dimensions of the tin-can. Measure first in centimetres and then in millimetres, as accurately as you are able to. Hooke's Law is fundamental in understanding simple harmonic motion. It applies to anything that stretches, even a little bit. In words, the "law" states that the stretch or extension of an object is proportional to the force that is extending it.	KMS, SK & EK
"You need about four rubber bands. Cut each rubber band with scissors and knot the cut ends so that you have a long, thin rubber strip. The strip should be at least 0.5 m long. (Note the alternative in Figure 5.)"	Sam, Ps, KMS
"With the cup empty, record the starting position of the pointer against the ruler. Consider the accuracy of the two scales on the ruler, and the significant figures in your measurement."	Ses, Sam &KMS

The written text in each practical work manual were read line by line to allow for memoing looking into differences and similarities in what the text is communicating line by line, one paragraph to another in one manual and in comparison, to other manuals as well. Across the three manual seven general codes/categories were formulated from the data.

4.9.4. Analytical framework: Interviews

A total of eight (8) interviews with three different stakeholders were conducted. The interviews, aimed to capture participant's practices to reveal the nature of practical work engaged in, their experiences, and factors affecting teaching and learning physics practical work for the third year of initial teacher training. The spiral data analysis approach (Creswell, 2013) was followed as a general data analysis approach, it was also deployed as an analytical framework where the participant's responds were read through line by line for familiarisation and memoing, then codification/categorisation and finally thematization, moving from more specific codes to more general themes. Creswell (2013) states that the spiral approach allows for the researcher to engage with the raw data and derive codes from the data as specified by the participants. The aim of the analysis was to understand human experiences as they explained or narrated through their responds and not to at the end quantify the data findings just like the Qualitative Content Analysis (QCA) approach as defined by (Mayring, 2014). Marying (2014) defines QCA as a mixed method approach to analysis where the assignment of categories to text is qualitative workings through passages and analysis of frequencies of categories as a quantitative step. The aim was to, in the end, understand the experiences and practices of the participants through the identification of patterns or categories to thematise the findings.

Therefore, a three-layered approach to the analysis of the interview data was followed. The first layer represents reading and memoing, or what is referred to as initial and open-ended coding of the responses on the interview data, where the responses are read through and summarised as presented by the respondents. The open codes are presented in their most specific nature as per the participant's responses without being broken down into simpler or familiar terms. The second layer represents the coding process where the initial codes are interpreted with meaning grounded from the understanding of literature, theoretical and conceptual frameworks explained in chapter 2 and 3 to establish or identify the pattern arising from the initial codes, which then allows for the categorisation of the responses. And the third and final layer represents the thematization of the patterns which is what is presented as sections in chapter 5. The established patterns or categories are then grouped under one big or umbrella idea called a theme. The themes are now most abstract and may be applied to anything under the phenomenon beyond what the respondents said. However, what the themes are referring to is specified through the code definition with respect to this study. Creswell (2013) refers to this multi-layered approach to analysis as the decreasing/increasing level of abstraction. Where the initial open-ended codes represent the ideas shared by respondents in their most direct/specific nature, meaning they are not unpacked or interpreted by the researcher. This is where the inductive analysis approach starts to pick out the initial open-ended codes. The open-ended codes are in their most specific nature and are now unpacked where a researcher categorises the initial codes to establish patterns of what the codes mean in relation to this study. The categories or now patterns in layer three are then thematised using an umbrella idea or a big idea that is less specific; hence it is referred to as the abstract layer. The themes are then the working ideas, which are used to present the study findings and interpret them for implications in the studied case and the phenomenon and finally to draw up some recommendations, all in an attempt to answer the research questions of the study. Creswell (2013) represents the analysis and findings diagram representing the spiral approach taken in one of his studies, which is also deployed in this study. See figure 3 below, adapted from Creswell (2013), showing the multi-layered approach to analysis, which is a similar structure approach I have taken in this study.

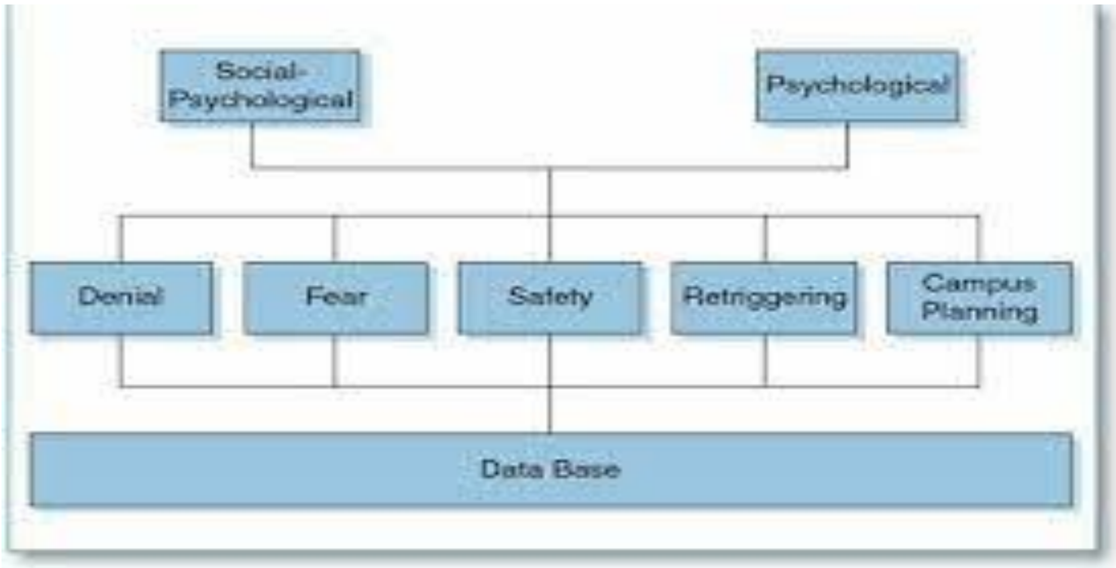


Figure 7: Layer of Analysis in the Gunman Case (Sourced from Creswell, 2013)

The analysis approach in the interview data in this study is four-layered instead of three, as presented in figure 8. The ground layer representing raw data from the interview transcripts as organised into summary statements referred to as initial open-ended codes patterned by axial codes, and then the axial codes are then categorised into themes, i.e., the big ideas of the study. Meaning-making of the data was influenced by the TPACK and ZPD as grounded in sociocultural theory. The generated themes and their definitions are, however, customised to this study though they may be interpreted with the above frameworks. Table 8 below present the seven themes and their definitions as implied in this study. Also see Appendix O for the coding process

Table 8: Emerging themes from the interviews with the participants

Theme	**Definition**
1. Practical work design for teaching and learning practical work.	Refers to statements describing the nature of practical work designed for 3rd year Physical sciences student teachers.
2. Opportunities and limitations to teaching and learning practical work.	Refers to statements describing things allowing or disallowing teaching and learning of the designed practical work
3. Recommendations to teaching and learning practical work.	These are points recommended for teaching and learning of practical work either online or in the laboratory
4. Digital technologies and use for teaching and learning practical work.	Points indicating students or teacher educators' use of digital technologies for teaching and learning practical work
5. Prior experience about teaching and learning practical work.	Student teachers and teacher educators' context: Indicates the initial knowledge and experience of teaching and learning practical prior the designed practical work.

6. Perception to teaching and learning practical work.	Represents teacher educators and students' perception about teaching and learning practical work.
7. Practical work teaching and learning approaches	Refers to pedagogical method choices taken in design and Implementation and learning approaches to drive the teaching and learning of the chosen practical work respectively.

Figure 9 below represent an excerpt of the multi-layered analysis approach followed to understand the interview data from all eight (8) participants.

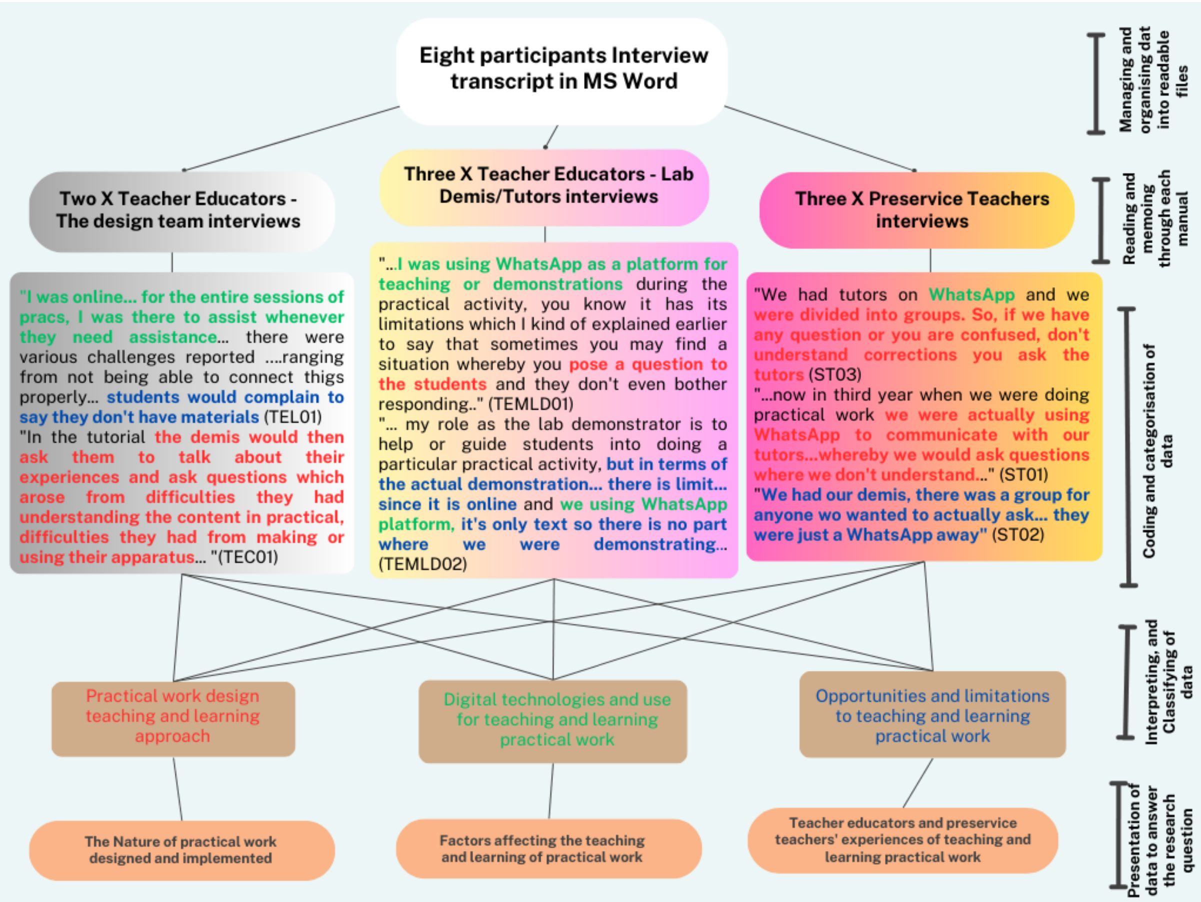


Figure 8: The spiral data analysis approach to understand the teaching and learning of practical work

From diagram 9 above five levels of the data analysis steps taken are depicted with the reading though the data, memoing and categorising not clearly shown on the diagram. To have clear view of the entire analysis process see Appendix N and O. Diagram 9 shows how we arrived to the different themes and how they answer the research questions asked in this study.

4.10. Research Rigor

Sargeant (2012) argues that in qualitative research, the study's rigour and quality are determined by the authenticity and trustworthiness of the data. The authenticity arises from the sampling techniques applied and chosen data collection procedures, the data's reliability, and the analysis arising from data triangulation. According to Sargeant (2012), data triangulation uses multiple data sources to inform a comprehensive perspective of the phenomenon under investigation. This study uses document review and interview methods to understand the teaching and learning of practical work in science teacher education programmes during the Covid-19 pandemic emergency remote learning. And a purposeful sampling technique is applied. Not everyone in the physics III course formed part of the interviews because the study aims to understand the phenomenon in greater detail and not to determine the outcomes or generalise.

The trustworthiness of the data can be declared as the interviews were recorded, so the recording serves as the primary source for confirmation. The recordings were further transcribed for analysis, which both the recording and the transcription were shared with the supervisors for access and to confirm if the transcription is a true reflection of what the interviewees have said.

Furthermore, the data analysis process was long and rigorous. This process took about almost a year to complete. Where the coding process was supervised from the first circle of coding which came back with comments that always had me go back to read and understand what coding is and what it entails. We held few meetings to read through my analysis approach to the data where the coding of the two data sources were either confirmed or refuted. One of the comments I received in the first circle of analysis was, "something is not gelling" this comment had me go back to the drawing board. At some point, Dr Mashayikwa said, "something is still not right", and the most encouraging comment was ", I have perused your attachments, and I am impressed". This last comment was the point of departure for confirmation of the generated codes. Together with my supervisor have done the code reliability check for practical 2 manual. However, only the first few codes were confirmed, with a suggestion to alter some of the codes that were rather not direct or descriptive enough for the analysed content. Codes such as Pedagogical Instructions (PI) and Pedagogical Approaches (PA) were revised to Knowledge management strategies to holistically represent the analysed text and its intention in the practical work design.

For interviews, the reliability checks for codes generated were done by an independent researcher who is not a science teacher nor a science teacher education specialist. However, the independent researcher has done research work on students' learning experiences in initial teacher education and has done work in other education research fields in the South African context. And in her coding of ST03 interview transcript, which was guided by the research questions as per our feedback meeting, codes such as agency, autonomous, simulations, digital readiness, instructions, students' engagements with practical work in high school, university, and as student teachers and many more came out see appendix H for her analysis of the transcript. Though we cannot quantify the reliability of the codes, the similarity of the independent researcher's codes to those reported in chapter 6 is quite visible and evident in the presented findings in chapter 5.

4.11 Chapter summary

The research method approach to this study is qualitative with a case study design and viewed through an interpretivist paradigm where context of the study and interviewees' stories are central to the analysis approach taken in the study. The researcher followed the spiral approach to data analysis presented in Creswell (2013) which allowed for inductive coding where we moved from specific to the data source codes to more abstract themes.

Chapter 5: Research findings presentation and analysis

5.1. Introduction

This study sought to understand "How teaching and learning of physics practical work unfolded in science teacher education in the online learning context". It particularly sought to understand the practical work activities design, implementation and learning process by the teacher educators in their respective roles and the preservice teachers in the warranted shift to remote teaching and learning modality due to COVID-19 regulations which ultimately accelerated the use of digital technologies, in education across South African universities (Moloi and Mhlongo, 2020). The study also explored the factors influencing the teaching and learning and experiences of teaching and learning practical work under the context where teaching and learning is facilitated mainly through various digital technologies. This chapter, therefore, presents findings from documents analysis and interviews data to answer the following main research question: How does a South African University respond to physical science practical work in the remote teaching and learning context? To help answer this main question, the following sub-questions were conceptualised:

1. What is the nature of physics practical work taught and learned in a teacher education course?
2. What are the factors influencing the teaching and learning of physics practical work?
3. What are the physics teacher educators' and pre-service teachers' experiences of practical work designed for remote teaching and learning?

This chapter presents the finding as analysed from two data collection methods employed. Presenting the codes and themes as found through the spiral data analysis approach as presented in chapter 4, guided by Creswell (2013). The findings are as per document analysis which included three practical work manuals used by the participants respectively, and Interview data analysis, which included a total of eight participants transcripts who are teacher educators made of three stakeholder playing different roles, the design and planning team comprising of one lecturer and one expert consultant, the implementing and facilitation team comprising of three lab demonstrators and three student teachers. The findings are organised and presented in three main themes which came out from the analysis of all the data sources. The first theme is **"Practical work design, teaching and learning approaches to physics practical work",** which addresses the artistic, pedagogical design of the practical work manuals, the delivery and the preservice teachers' learning approach to practical work they engaged in, i.e., what teacher educators intended to teach and how they intended to teach it through practical work and also how the preservice teachers engaged with the intended practical work activities. There are three sub-themes that emerged from this theme, and these are "*The practical work design*", which speaks to the intended and unintended learning objectives and "*The pedagogical approach employed for practical work activities*", which focuses on how the teacher educators intended to teach and "*The learning approaches to approaches to practical work*" which address various strategies that preservice teachers had to employ in order to complete the three practical work activities they engaged in. This first theme assisted the study in answering the first research question which sought to understand the nature of practical work engaged in for physics preservice teacher education course.

The second theme that came out from the interview analysis is **"The use of digital technologies for teaching and learning practical physics work",** which addresses the digital devices and tools used and how they influenced the teaching and learning of practical work. Finally, the third theme is **"The opportunities and limitations to the teaching and learning practical work",** addressing the experiences of both teacher educators and preservice teachers in teaching and learning the designed practical work activities in the current learning context in the digital era. The second and last themes answer the last two research questions interchangeably. All three themes answer the main research question in-depth and also raise more questions for further research in extension to the current study as per some of the recommendations suggested by the participants. The three themes present the approaches to teaching and learning of practical work, revealing how each of the participants went about to ensure that their roles are played and their parts are completed in the present teaching and learning context.

5.1. Practical work design, teaching and learning approaches to physics practical work.

Millar (2010) highlights in his practical work analysis booklet that "practical work activities differ in their learning objectives and what students had to do" (p. 5). It was then imperative to first understand the practical work design, the teaching and learning approaches, which reveals the structure of the activities as in what need to be learnt and how it is to be learnt, how it was presented to the preservice teachers and they received and engaged in the presented practical work activities. The findings reveal that preservice teachers engaged in kitchen table (KTPW) practical work, which they had to do at home with improvised materials. The practical work activities are guided inquiry-based in nature with the "[6]cookbook recipe" approach. The learning objectives were made clear in the guide with a given logical structure on what students had to do and what they had to learn. Sub-theme 1 represents the learning objectives, sub-theme 2 represents the teaching approaches and sub-theme three presents the learning approaches. The following section details the findings and analysis of all the three sub-themes.

5.1.1. Practical work design

The practical work manuals present the teaching strategy the teacher educators chose, it serves as a work guide on what to know, what to do and how to do it. The structure and layout of the practical work manuals is made of text and picture and/or diagram which preservice teachers need to read and also refer to the diagrams and pictures to guide their processes in engaging with the practical work activities. These various forms of communication and what is being communicated on the manual guide then reveals the design of the practical work engaged in, that is the design unpacks the choice of content shared in each manual, the objectives of the content and how it is also shared on the document.

5.1.1.1. Practical work design as per practical work manual analysis

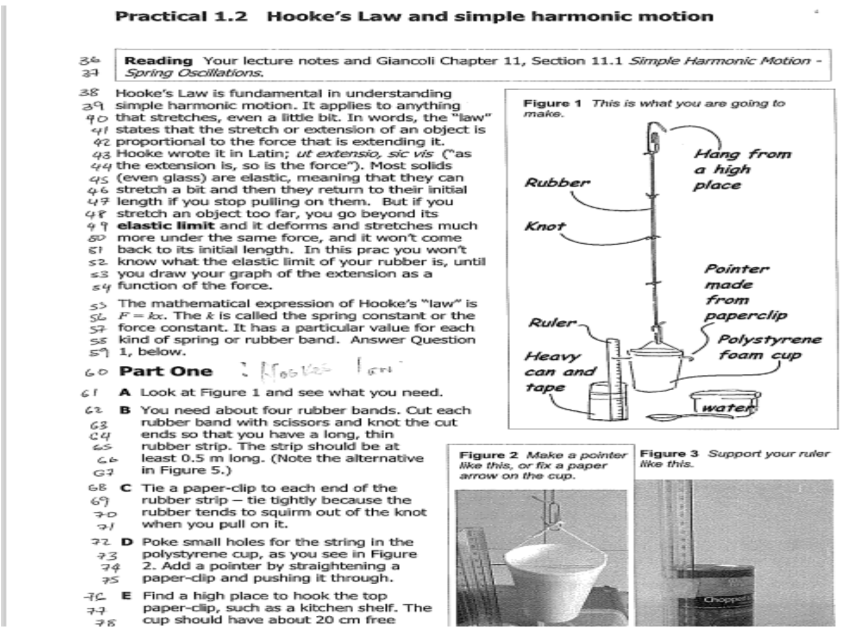
From the three analysed practical work manuals, nine codes emerged as what the design represents overall, with implied teaching approach and instructions together with the learning objectives. While each practical manual represents different scientific ideas and different materials used for the inquiry the rising codes emerged across the three manuals. The codes are scientific knowledge (SK) which speaks to the scientific knowledge focused on in each manual, Simple accessible material (Sam) which speak to different materials that preservice teachers had to find and use to drive the inquiries, practical skills (Ps) and these are different hands-on procedural knowledge that preservice teachers should be able to apply or gain from the inquiries , scientific enquiry skills (Ses) which are preservice teachers' ability to understand the objectives of the inquiry, follow through instructions to apply or gain scientific skills which are to formulate hypothesis, collect analyse and interpret data. All these knowledge structures were managed with specific strategies communicated through texts or diagrams/illustration as teaching and guiding instructions labelled Knowledge management strategies (KMS) for student teachers. Also emerging from the data but not so central to the objectives of the practical work activities are three knowledge components; Technological knowledge (TK), Everyday

[6] This study refers to Cook-book recipe as the enquiry process design that teacher educators gave the students to guide their learning of practical work. Just as described in Millar (2010) it is a worksheet of step-by-step guide of what students needed to do, how to do it and what to learn.

Knowledge (EK) and History of Science (HoS). This section present findings of practical work manual one, two and three respectively and close with a comparison of the three.

The practical work 1 manual design data presentation and analysis.

Practical one had two parts to it, where students were required to master two physics concepts. The first part suggested that students were required to know and understand the concept of Measurements, and the second concepts were Hooke's law and simple harmonic motion, as presented in figure 10 below. For students to get to construct their understanding of these two concepts, the teacher educators gave a guided approach or procedure for students to follow as they get hands-on with connecting the simple improvised materials. The procedure is shown with the bolded letters indicating a step-by-step guide of what students had to do. The knowledge construction processes are directed through instructions together with illustrations to help students conceptualise and visualise the processes they have to undergo as they construct their own knowledge. It is clear in figure 10 below that the teacher educator wanted to have the students understand the concept of elasticity in Hooke's law as it is written in bold in the theory provided to and the concept of elasticity was associated with the word stretch which students in one way or the other use it in their everyday lives without referring to specific materials as they would in physics.



Practical 1.2 Hooke's Law and simple harmonic motion

Reading Your lecture notes and Giancoli Chapter 11, Section 11.1 *Simple Harmonic Motion - Spring Oscillations.*

Hooke's Law is fundamental in understanding simple harmonic motion. It applies to anything that stretches, even a little bit. In words, the "law" states that the stretch or extension of an object is proportional to the force that is extending it. Hooke wrote it in Latin; *ut extensio, sic vis* ("as the extension is, so is the force"). Most solids (even glass) are elastic, meaning that they can stretch a bit and then they return to their initial length if you stop pulling on them. But if you stretch an object too far, you go beyond its **elastic limit** and it deforms and stretches much more under the same force, and it won't come back to its initial length. In this prac you won't know what the elastic limit of your rubber is, until you draw your graph of the extension as a function of the force.

The mathematical expression of Hooke's "law" is $F = kx$. The k is called the spring constant or the force constant. It has a particular value for each kind of spring or rubber band. Answer Question 1, below.

Part One

A Look at Figure 1 and see what you need.

B You need about four rubber bands. Cut each rubber band with scissors and knot the cut ends so that you have a long, thin rubber strip. The strip should be at least 0.5 m long. (Note the alternative in Figure 5.)

C Tie a paper-clip to each end of the rubber strip — tie tightly because the rubber tends to squirm out of the knot when you pull on it.

D Poke small holes for the string in the polystyrene cup, as you see in Figure 2. Add a pointer by straightening a paper-clip and pushing it through.

E Find a high place to hook the top paper-clip, such as a kitchen shelf. The cup should have about 20 cm free

Figure 1 *This is what you are going to make.*

Figure 2 *Make a pointer like this, or fix a paper arrow on the cup.*

Figure 3 *Support your ruler like this.*

Figure 9: Practical work one manual design and structure

Diagram 10 above present the sample structure and design of practical manual one which sample the layout of the practical work manuals. What is presented in the diagram below is the specific conceptual knowledge which is driven scientific idea that the preservice teachers need to know “Hooke’s law”. Presented in paragraph one of the texts is the theoretical grounding of what need to be known, under part one is the teaching instruction and steps which the preservice teachers need to follow in order to complete the practical work activity which is presented in labelled diagram, while figure 2 and 3 present pictures of the real materials that the preservice teachers had to use to illustrate their supposed reality when they do the task. While figure 1 is just a labelled diagram of the entire setting, figure 2 and 3 are pictures used to instruct and show preservice teachers on how their setup need to look like. Table 9 below present the findings, these are codes that emerged from the analysis of practical work one manual and the number of times each code came out. The occurrence of the code indicates the emphasis or the focus of the practical work activity.

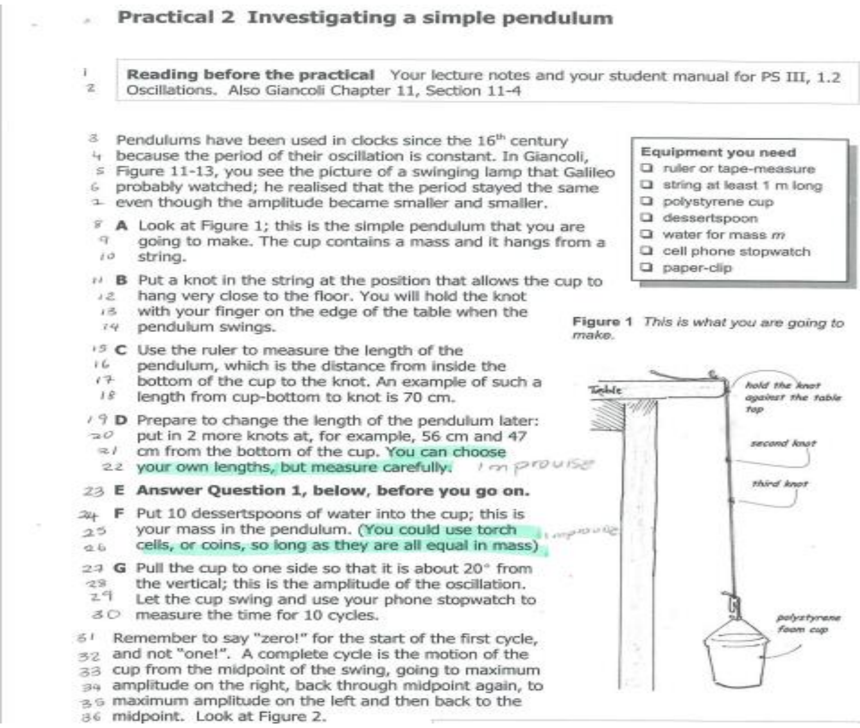
Table 9: Emerging codes and their occurrences in Practical one manual

Codes	Occurrence
EK- Everyday Knowledge	6
KTPW- Kitchen Table Practical Work	2
Ps- Practical skills	12
KMS- Knowledge Management Strategies	43
Sam- Simple accessible materials	18
Ses- Scientific enquiry skills	26
SK- Scientific Knowledge	32
TK- Technological Knowledge	7
HoS- History of Science	0
Grand Total	**146**

Table 9 above suggests that the learning objectives for practical one manual were centred on driving scientific ideas (SK) and scientific enquiry skills (Ses) with the support of simple, accessible materials which the preservice teachers had to manipulate under guidance which are direct procedural guide-cookbook recipe as per the manual to get to know what they were intended to know so that they can arrive at a conclusion through responding to questions asked in the worksheet. There is also everyday words used to either describe scientific terms or to rather associate with the driven science concepts such as *“It applies to anything that stretches, even a little bit”* as stated in the diagram 10 above.

The practical work 2 manual design data presentation and analysis.

The structure and design of practical work two manual is not different from practical work one manual. The layout of the manual is largely made of text which present brief theory and background on the scientific idea that need to be known and the instructions of what need to be done and how it is to be done. The text is supported by a labelled diagram as in practical work one manual and a list of materials that students need to use to connect as they follow the instructions. Figure 11 below present extract of data as per practical 2 manual. The teacher educator is driving the conceptual idea of focus in the manual which is "Pendulum" by presenting it historical background with the scientist behind the work in the 16th century. Even though real pictures of the apparatus are not presented in the manual, the presented diagram is used as an illustration of what the preservice teachers need to make.



Practical 2 Investigating a simple pendulum

Reading before the practical Your lecture notes and your student manual for PS III, 1.2 Oscillations. Also Giancoli Chapter 11, Section 11-4

Pendulums have been used in clocks since the 16th century because the period of their oscillation is constant. In Giancoli, Figure 11-13, you see the picture of a swinging lamp that Galileo probably watched; he realised that the period stayed the same even though the amplitude became smaller and smaller.

Equipment you need
- ruler or tape-measure
- string at least 1 m long
- polystyrene cup
- dessertspoon
- water for mass *m*
- cell phone stopwatch
- paper-clip

A Look at Figure 1; this is the simple pendulum that you are going to make. The cup contains a mass and it hangs from a string.

B Put a knot in the string at the position that allows the cup to hang very close to the floor. You will hold the knot with your finger on the edge of the table when the pendulum swings.

C Use the ruler to measure the length of the pendulum, which is the distance from inside the bottom of the cup to the knot. An example of such a length from cup-bottom to knot is 70 cm.

D Prepare to change the length of the pendulum later: put in 2 more knots at, for example, 56 cm and 47 cm from the bottom of the cup. You can choose your own lengths, but measure carefully. Improvise

E **Answer Question 1, below, before you go on.**

F Put 10 dessertspoons of water into the cup; this is your mass in the pendulum. (You could use torch cells, or coins, so long as they are all equal in mass) Improvise

G Pull the cup to one side so that it is about 20° from the vertical; this is the amplitude of the oscillation. Let the cup swing and use your phone stopwatch to measure the time for 10 cycles.

Remember to say "zero!" for the start of the first cycle, and not "one!". A complete cycle is the motion of the cup from the midpoint of the swing, going to maximum amplitude on the right, back through midpoint again, to maximum amplitude on the left and then back to the midpoint. Look at Figure 2.

Figure 1 *This is what you are going to make.*

Figure 10: Practical work two manual design and structure

From figure 11, practical two manual design suggests that students are guided through their process of knowledge construction with instructions in text and illustrations. Still, the students need to get hands-on with improvised simple materials. Learning objectives is that preservice teachers need to know and understand the scientific idea (SK) driven, know and develop further scientific enquiry skills (Ses) while they are also getting hands on to be able to make conclusions about what they know from what they did following the instructions or their own discretion. Table 10 below present findings as codes that emerged from the analysis of practical work two manual.

Table 10: Emerging codes and their occurrences in Practical 2 manual

Codes	Occurrence
EK- Everyday Knowledge	3
HoS- History of science	1
KTPW- Kitchen Table Practical Work	0
KMS- Knowledge Management Strategies	25

Ps- Practical skills **Sam-** Simple accessible materials **Ses-** Scientific enquiry skills **SK-** Scientific Knowledge **TK-** Technological Knowledge	11 10 22 22 2
Grand Total	**96**

Table 10 above suggests that the learning objectives for practical 2 manual were centred on driving scientific ideas and scientific enquiry skills with the support of simple accessible materials which the student teachers had to manipulate under direct procedural guide "cookbook recipe approach" where they are instructed on what to do and how to do it to get to know what they were intended to know so that they can arrive at a conclusion about the scientific knowledge through responding to questions asked in the worksheet.

The practical work 3 manual design data presentation and analysis.

The structure and design of practical work three manual is not different from practical work one and two manuals. The layout of the manual is largely made of text which present the instructions of what need to be done and how it is to be done in knowing the scientific idea driven. Students had to know how to make a standing wave and ensure that they are able observe the characteristic of a standing wave from the models they have made with the prescribed materials. The text is however supported by not a labelled diagram but a real picture of the wave model made with straws in figure 1. Figure 1 in practical work three manual as shown in figure 12 below is used as an illustration of the wave model the preservice teacher were supposed to build. The layout as in practical work manual 2 also features a box with a list of materials students had to use to build the wave model. Figure 12 below present extract design and structure of practical work three manual.

Practical 3 Investigating waves on a wave model

Reading before the practical Your lecture notes and your student manual for PS III, 1.2 Oscillations. Also Giancoli Chapter 11, Sections 11-8 to 11-12.

Read through the questions before you start making the wave model, so that you understand where we are going with this.

Equipment you need

- ruler or tape-measure
- a roll of stickytape
- about 24 plastic straws
- cell phone stopwatch
- 16 paper-clips

A Look at Figure 1; this is the wave model that you are going to make. The stickytape is stuck on top of the table and stuck to something heavy at the bottom.

B To make it, lay about 24 plastic straws on the table, parallel and spaced by the width of your finger. The tips should be in a straight line. The row of straws will be approximately 60 cm to 70 cm long.

C Pull out about 1 m of stickytape from the roll and lay it across the middle of the row of straws. Press the tape onto the straws and make sure they are sticking to the tape.

D Don't cut the tape. Leave about 20 cm of tape clear at the top of the row, to stick on the table, and leave the rest clear at the bottom.

E Stick the roll of stickytape to a heavy object on the floor, so that the tape is stretched fairly taut. You should see the straws line up parallel to each other.

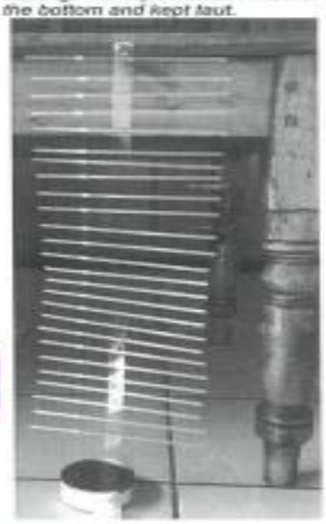
F Now give the tip of the bottom straw a sideways tap, and watch the pulse travel up the top-most straw. You can see this most clearly when you view the tips from the side.

G You will see a pulse reflected from the top of the row that travels back down to the bottom.

H Answer Questions 1 and 2.

Note: In this dry weather, you may find that the straws readily get an electric charge and are all attracted to your fingers. Try giving the bottom straw a push with the end of a loose straw, instead of bringing your hand near the straws.

Figure 1 The wave model you are making. The tape must be held at the bottom and kept taut.



Wave interference and how to make a standing wave

Standing waves are a key concept in the quantum mechanical understanding of the atom.

If the reflected pulse coming down meets a new pulse travelling up the row, these two might reinforce each other (in constructive interference) or cancel each other for an instant (in destructive interference). If you can send new pulses upward at just the right frequency, you can set up a standing wave. Up-coming and down-going waves will cancel each other at a certain point near the middle – you will see one or two straws in the middle of the row that hardly move at all. This point is called a node. In the top and the bottom halves of the row, there a few straws that swing widely; these positions are two antinodes. Look at Figure 2.

Figure 11: Practical work three manual design and structure

From figure 12, practical three manual design suggests that students are guided through their process of knowledge construction with instructions in text and illustrations. Learning objectives is that preservice teachers need to know and understand the scientific idea (SK) driven, know and develop further scientific enquiry skills (Ses) while they are also getting hands on to be able to make conclusions about what they know from what they did following the instructions or their own discretion. Table 11 below present findings as in codes that emerged from the analysis of practical work three manual. The findings in practical 3 manual suggest that the concept of focus is waves and students had to build a wave model and see how the wave occurs through the connection of plastic straws. This practical work design takes into consideration precaution measures students had to care for in order to do observations of the concept. Table 11 below summarises the code analysis of the whole practical work three manual.

Table 11: Emerging codes and occurrence in Practical work three manual.

Codes	Occurrence
EK- Everyday Knowledge	4
HoS- History of Science	0
KTPW- Kitchen Table Practical Work	1
KMS- Knowledge Management Skills	33
Ps- Practical skills	10
Sam- Simple accessible materials	10
Ses- Scientific enquiry skills	16
SK- Scientific Knowledge	32
TK- Technological Knowledge	5
Grand Total	**111**

The findings as indicated by emerging codes and occurrences as per analysis suggest that students are driven to knowing the scientific knowledge and develop scientific enquiry skills. While the central objective from the practical manual appears to be scientific knowledge (SK) structure amongst the other science knowledge structures. Preservice teachers had to manipulate the simple improvised materials, they were doing that to observe and understand a wave and their occurrence in a wave model.

All practical work manuals compared.

The three practical work manuals were compared, and the comparison suggest that there are three central learning objectives to the practical work. These are, students to grasp the science knowledge or rather the content knowledge as taught in the lectures, students to gain scientific enquiry skills and practical skills. Table 12 below highlights that the different codes and their occurrences in each manual compared.

Table 12: Emerging codes and occurrences in all three practical work manuals

Codes	Occurrence in PW 1	Occurrence in PW 2	Occurrence in PW 3
EK- Everyday Knowledge	6	3	4
HoS- History of science	0	1	0
KTPW- Kitchen Table Practical Work	2	0	1
KMS- Knowledge Management Strategies	43	25	33
Ps- Practical skills	12	11	10
Sam- Simple accessible materials	18	10	10
Ses- Scientific enquiry skills	26	22	16
SK- Scientific Knowledge	32	22	32
TK- Technological Knowledge	7	2	5
Grand Total	146	**96**	111

From table 12 above, indicate that the know management strategies are used to drive the knowledge of key scientific ideas, instruct for preservice teacher to use or acquire scientific enquiry skills by using the simple accessible materials practically hands-on to arrive at conclusions. Figure 13 below compares each emerging code as they occur in the three practical work manuals.

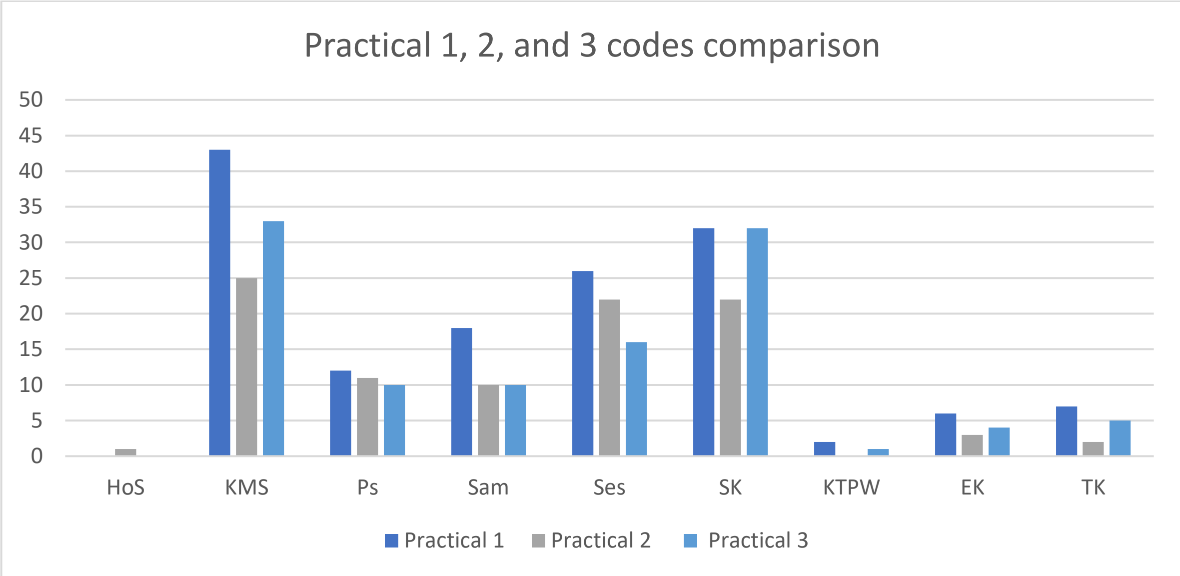


Figure 12: graphical representation of codes occurrences in practical 1, 2 and 3

Figure 13 above shows that knowledge management strategies infused in each manual played a huge role in driving and facilitating learning. The practical work design indicate that the objectives were highly centralised towards scientific knowledge component accompanied by two type of skills, which are Scientific enquiry skills and Practical skills as mentioned above. However, the central knowledge and skills sets were supported by three other knowledge components which are the history of science, everyday knowledge, and technological knowledge for full completion of the practical work activities by the preservice teachers. Above all, across all three, the handy work had to happen in non-traditional laboratory with non-sophisticated apparatus.

5.1.1.2. Practical work design as per the interviews

To gain a deeper understanding of the practical work design, I further asked the design team questions about the pedagogical thinking and reasoning behind the design. With the aim to dig deeper into why and how they decided on the home-based kitchen table practical work as highlighted in the practical work manuals. From the analysis, the thinking and reasoning behind the chosen practical work was centred around subject knowledge and pedagogical knowledge. The design revealed that other forms of practical work were implemented in previous years with the same group of students since they started with remote learning. However, for the current year Kitchen table practical work were chosen and the main aim was to engage preservice teacher's in hands-on practical work to know and understand the scientific concept taught in the lecture. It was important that they engage preservice teachers in hands-on practical work were simple materials are connected and manipulated to gain practical skills and construct specific science content knowledge. Secondly, the design team mentioned that they were also looking to train and prepare the preservice teachers for the ordinary South African schools where learning still occurs physically. When asked about the reason behind the chosen approach to practical work, the design team said:

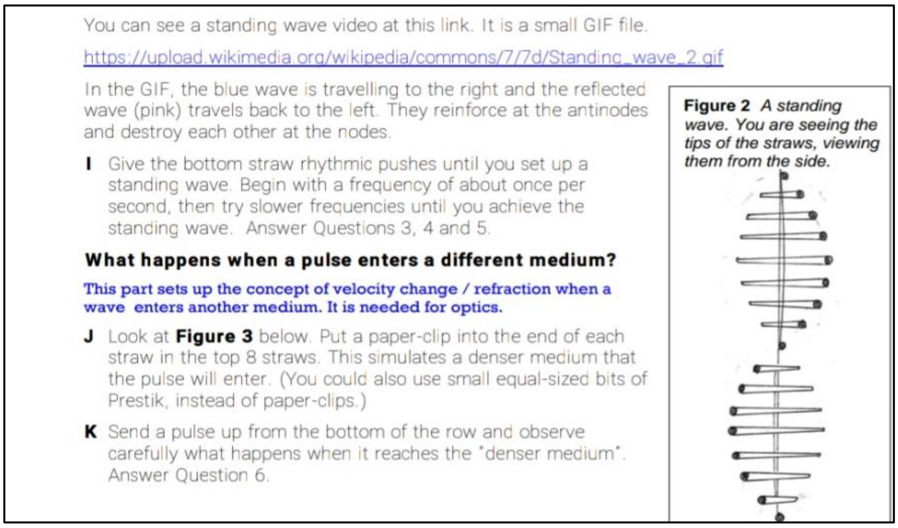
Consultant's response
"OK we are training teachers and with or without Covid these teachers are supposed to go to schools and most of our schools, the majority of our public schools requires teachers to be present in the classroom. It requires teachers to actually perform the practical with the students so it's important that our teachers who goes into the field they do have that practical aspect of the skills that are required to perform whatever practical that they have to perform…" (TEC01) *they had to go and find something else and it might be the thread might have been a piece of copper wire and that learning to cope with a difficulty and overcome a difficulty is an essential part of a teacher's professional education nature doesn't present itself in standardized equipment you got to heavily initiative and the ideas to make something that works so that the children in school will be able to see this phenomenon." (TEC01)*
Lecturer's response
"So, what I was doing then with the students, it was to give them that practical skills through the kitchen table pracs... So, that practical skill is what I wanted them to get, how to connect all those apparatuses and how to work with the materials to see a particular concept that they had to see through that connection". (TEL01) *"so since we started with this online thing last year I gave simulations for this particular 3rd year group and with the challenges that I had with simulations I then thought that it would be best to have pracs in another format you know trying to give the practical … so the pracs that I then went for was your simple kitchen table pracs where students were required to get those easy home material and then they connect it and then conduct the practical. (TEL01)* *So, the idea was that they should use whatever that is available to them to construct what was supposed to be done as long as it's going to show a conceptual understanding and the conceptual process that we wanted them to see with that particular prac." (TEL01)*

5.1.2. Teaching approaches to physics practical work

Teaching is an artistic knowledge. It is both a knowledge and a skill which in its own right comprise various knowledge components. While the above sub-theme presents the knowledge base for practical work design, this sub-theme presents the knowledge base for teaching the designed practical work. Practical work teaching approach as one would summarise it comprise the approach included in the practical work manuals and the teacher educators' practices as they mediate the learning as per their interview responses. The teaching approaches in this study are revealed through the practical work manual guides and also the interviewees responses, both data sources reveal the intended and unintended techniques employed in the process of teaching the physics practical work.

5.1.2.1. Knowledge management strategies as per the practical work manuals

Practical work manual serves as a teaching guide or as an instructional guide in the absence of the teacher, communicating whatever the teacher wants the students to know or do. The texts and diagrams/pictures as presented in the previous section communicate in various ways and different things to make sure that the intended learning objectives and learning steps are highlighted to the students. From the three manuals we see the and the illustration text presented in various forms. The text is written with same font and the emphasis points are bolded and/or Italicised in the manual to communicate intensions and meaning of the text, and diagrams and/or pictures and/or GIF links are also included in the manuals to illustrate the concepts under study. Figure 14 below present the overall teaching approach as found in the three practical work manuals.


You can see a standing wave video at this link. It is a small GIF file.

https://upload.wikimedia.org/wikipedia/commons/7/7d/Standing_wave_2.gif

In the GIF, the blue wave is travelling to the right and the reflected wave (pink) travels back to the left. They reinforce at the antinodes and destroy each other at the nodes.

I Give the bottom straw rhythmic pushes until you set up a standing wave. Begin with a frequency of about once per second, then try slower frequencies until you achieve the standing wave. Answer Questions 3, 4 and 5.

What happens when a pulse enters a different medium?

This part sets up the concept of velocity change / refraction when a wave enters another medium. It is needed for optics.

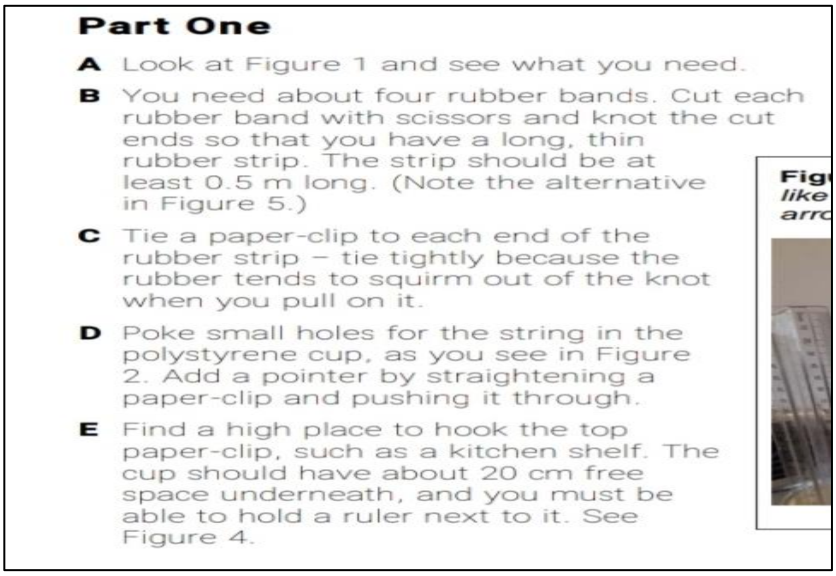
J Look at **Figure 3** below. Put a paper-clip into the end of each straw in the top 8 straws. This simulates a denser medium that the pulse will enter. (You could also use small equal-sized bits of Prestik, instead of paper-clips.)

K Send a pulse up from the bottom of the row and observe carefully what happens when it reaches the "denser medium". Answer Question 6.

Figure 2 *A standing wave. You are seeing the tips of the straws, viewing them from the side.*

Figure 13:The use of text, GIF links and diagrams to drive learning through the practical work manuals.

As indicated in the findings and analysis in the above section teaching approaches are the cornerstone of the practical manual. Knowledge Management strategies (KMS) occur more often in each practical work manuals, this study assumes that each time KMS is coded on the manuals it would be a teacher giving direction or instruction on what to know, how to know it and what to do sometimes. It is through the guiding procedural instructions and the relevant pedagogical instructions that students become aware of what they need to know, what they need to do and how they need to do it. The practical work manuals are guides through words in textual manner organised as a worksheet that presented a step-by-step procedure for students to follow. The text is the supported by illustrations in terms of pictures, diagrams and links that redirect students to have a picture of what they need to know or do and what it looks like. Figure 15 below as in Practical 1 Manual present a sample of the textual step by step guide on what materials students need and how they need to connect it



Part One

A Look at Figure 1 and see what you need.

B You need about four rubber bands. Cut each rubber band with scissors and knot the cut ends so that you have a long, thin rubber strip. The strip should be at least 0.5 m long. (Note the alternative in Figure 5.)

C Tie a paper-clip to each end of the rubber strip – tie tightly because the rubber tends to squirm out of the knot when you pull on it.

D Poke small holes for the string in the polystyrene cup, as you see in Figure 2. Add a pointer by straightening a paper-clip and pushing it through.

E Find a high place to hook the top paper-clip, such as a kitchen shelf. The cup should have about 20 cm free space underneath, and you must be able to hold a ruler next to it. See Figure 4.

Figure 14: Practical work procedure guide as designed in the practical work manual

Figure 15 above present the sample of the step-by-step guided procedure for preservice teachers to successfully access all the intended knowledge from the activity. Preservice teachers under part one A in figure 15 above are instructed to *"Look at figure 1"* for further information. This is a guiding instruction which the preservice teachers would then know what to do **"Look"** and where to look **"Figure 1"** in the practical work manual they are working with. The text then leads the preservice teachers to a diagram or a picture that would allow the preservice teacher to see what they are intended to see as per the instruction in the text, the diagrams and pictures are presented in figure 16 below.

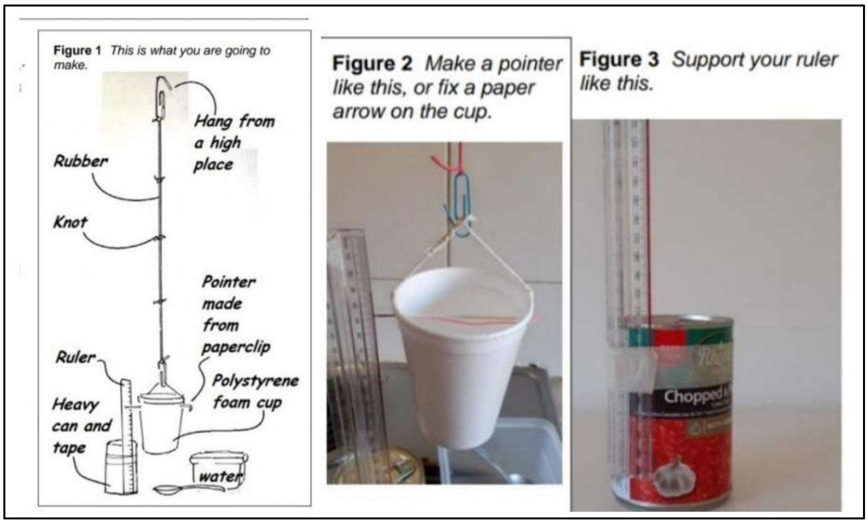


Figure 15: Sample of diagrams and pictures as a form of illustration on how the connections need to look like upon completion (Adopted from manual for practical work 1.

Figure 16 below illustrate what they need as in the materials as shown in figure 1, 2 and 3, the needed materials are also labelled in text in figure 1. The diagrams and pictures are also used to illustrate how their connections need to look like when they are done in the absence of the teacher to demonstrate in front of the preservice teachers. Of great notice in the manuals is the emphasis on the materials used which are part of the instructing text, diagrams and pictures and they are also highlighted as a list of materials or equipment needed to conduct the practical work activities on a separate box. These specific box with a list of materials is part of each practical work manual, indicating different materials for different conceptual learning and enquiry. Figure 17 below present the list of equipment needed for each of the practical work activity as appearing in the manuals.

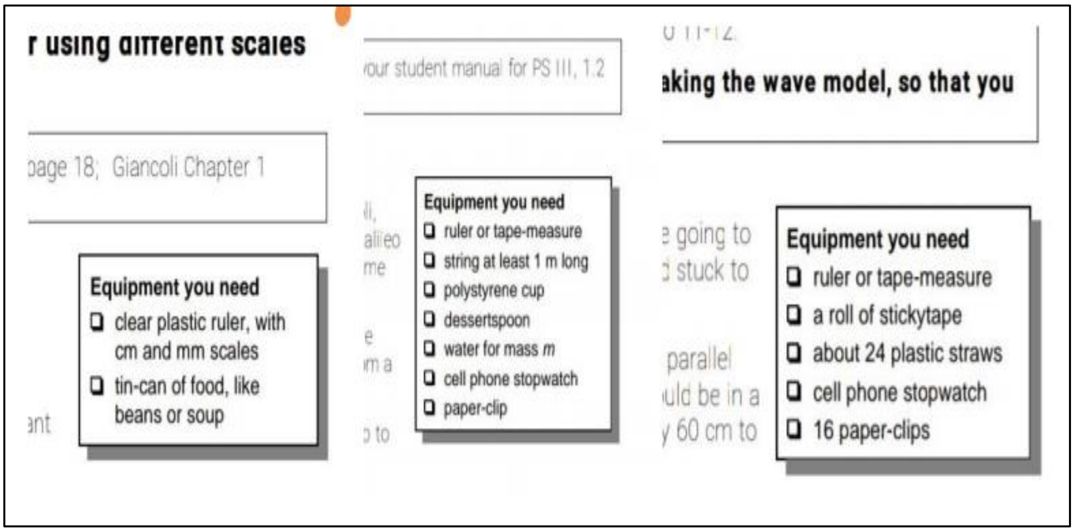


Figure 16: Simple materials required for use as sourced from practical work 1, 2, and 3 manuals respectively

Figure 17 above present the different materials students had to gather to conduct their practical work activities. Box 1 represent the list for students to do measurements of the set materials, which the list is very specific that a clear plastic ruler is required for cm and mm scales. Box 2 which represent Hooke's law, the teacher educators' instruction is specific to the length of the string and the type of cup required for the work to be done. In Box 3 there is an introduction of plastic straws and a roll of sticky tape. Similarities in the materials indicate across the practical work activities is that the preservice teachers are required to measure, but they measure different things which also speak to the different science concept they are inquiring about. The analysis of the teaching approaches on the manuals confirms that central to the practical work activities is the Scientific knowledge and the scientific enquiry skills, because the similar apparatus found in the three lists in figure 17 are used different following the scientific idea being driven.

5.1.2.2. Knowledge management strategies and practices as per interviews

The teacher educators' practices in this case talks to knowledge management strategies and practices, which are instructional techniques put in place to mediate learning and the actual pedagogic actions in facilitating learning of the designed practical work. The knowledge management strategies refer to the structuring of the teaching approaches to facilitate the learning of practical work in the presented educational context of the university, teacher educators and that of the student's teachers. And knowledge management practices refer to action steps taken by the teacher educator to facilitate or mediate the learning of practical work designed. Knowledge management strategies and knowledge management practices became the central code groups for the current them. They refer to what teachers' educators did during the practical work session to ensure that and assist preservice teachers in engaging and completing the practical work activities. This subsection present findings from teacher educators' interview responses and triangulated by preservice teachers' interview responses.

As presented in the case study context in chapter 4, practical work was previously engaged with in a physical science laboratory with designated and sophisticated scientific apparatus. However, due to the Covid-19 induced shift to remote working conditions, teaching and learning also occurred remotely and out of the usual science laboratory for the participants and that warranted a rethinking of their teaching and learning practices. The interview responses paint a picture of how teacher educators stepped in through strategy and practice to ensure continued hands-on practical work for the aspiring physical science teachers. While the practical work manuals reveal the design and the intended teaching and learning approaches. It does not reveal the actual teaching and learning approaches, strategies and practices that actually happened in the processes. Participants' in the interviews reflected on their strategies and practices the put in place in actually teaching and learning practical work respecting, findings are presented below.

Knowledge management strategies

In this case the lecturer worked alongside lab demonstrators (Lab demis) to implement the designed practical work. The finding reveals that the lecturer had different strategies in place to coordinate the implementation of the designed practical work. Interview analysis reveals there were organisational or administration strategies thought of and put in place more than actual teaching strategies. Teacher educators created an online presence to connect with the preservice teachers, that is the ULMS, WhatsApp and emails were made key platforms for teaching and learning processes to unfold smoothly. Prior to the actual practical work session, the design team thought and put ways to facilitate assessment or evaluation of the design practical work and to also have preservice teachers to give feedback on the work they done from their respective locations. A University Learning Management System (ULMS) was utilised for accessing practical work manuals for all the instructions and to also submit their written reports for assessment and for feedback on assessment. Moreover, teacher educators used the practical work manuals to guide submission through instructions. Which according to the consultant, required preservice teachers to work through MS word processed document where they could input mathematical equations as well, pictures/photographs and/or videos of the materials connected for lab demis to be able to see what the students actually did as they assess the submitted work. The thought behind photos and videos according to the lecturer was evidence for them to see that students really followed through the guides and used materials as prescribed in the manuals. In a nutshell, even though the preservice teachers were engaged in kitchen table practical work, the work was administered through digital tools, WhatsApp and the ULMS at most, for feedback between preservice teachers and the teacher educators. When asked about the how they managed submissions from preservice teachers, the lecturer and the consultant had the following to say:

Consultant's response
"well it's because it was online, they were going to have to upload it on the university learning management system…" (TEC01) *"… task sheet which had the questions and it was an Ms word version that they could type into, they could type in answers there and we asked them to use a different colour to make it easier for the demies to see the … it was really just the ability to use MS word to use the maths … equation function in Ms word and then … attach photographs of the apparatus and two cases they had to do a little video … and they needed to upload that" (TEC01)*

Lecturer’s response
“…they're not just claiming that they're doing it while they're not. So, we required them to submit short video clips of them connecting and actually performing the practical so they had to submit that together with their lab reports and to make sure that they do that you know in some pracs…” (TEL01)

Moreover, implementation required setting up the environment for the facilitation. The design team stated that they divided the students into groups of three and allocated two lab demis each to manage the number of students they had. The actual facilitation happened on a WhatsApp group at a specific time slot, teacher educators where open to have communication with the students, on WhatsApp and email. The participants’ reflection reveals that there was no particular teaching practice strategy that the facilitation had to follow. The lab demis had to use their expert knowledge to drive and facilitate the learning of practical work activity for each week. Teacher educators reflect on the administration strategies for knowledge management below, dividing the students into groups, creating WhatsApp groups for engagements and communication:

Lecturer and Consultant’s responses
“… with the implementation part you know you're having more than 100 students so you can't really attend to all of them in two hours as one person you know. … you have two tutors who are assisting in that particular group … tutors are engaging with the students … on those WhatsApp platforms that they were using for pracs …” (TEL01) *“In these particular pracs um there wasn't really a teaching strategy that the demies would use … On this third year the overall strategy was that the students needed to first of all make the equipment take measurements answer questions which compared the results they get for their measurements with the theoretical results …” (TEC01)*
Lab demonstrators’ responses
“…It was a matter of practicals are now facilitated on WhatsApp, as a demi you need to find means on how you can improvise and come up with certain teaching strategies or techniques that you think are going to help you in helping learners learn best.” (TEMD01) *“…my lab partner and then ask if he is able to get into WhatsApp and try to talk with the students and try to make them work but that is the only way to do it because we are paired ...” (TENMD01).*

Knowledge management practices

The teacher educators indicated that there was no particular teachings strategy though of to guide the facilitation and that lab demis had to each think of ways to help the preservice teachers in learning of practical work. The lecturer indicated that they had to have briefing and debrief discussions about practical work during the lecture session. On the other hand, for lab demis' practices during the practical work sessions, discussions in a form of questions and answer were common across the three working groups. Lab demonstrators indicated that due to the fact that teaching and learning occur through online platforms, all they could do was to have discussions driven through Q&A as demonstrations were impossible for facilitation. When asked about the teaching practices they employed during the practical work sessions, the Lecturer and Lab demonstrators said:

Lecturer's responses *"… so we did we did our practical work a bit differently now that everything is online … practical work was to some extent embedded in the lecture sessions you know where you explain the process in one lecture before the practical, explaining what students are supposed to be doing and then you sort of like touch on the practical work and the processes and outcomes in the following lecture after the practical you know. So, students would have a practical session with their lab demonstrators … if people are participating, I would see questions that they are asking, and I would encourage tutors to respond to those questions" (TEL01)*
Lab demonstrators' responses *"And I usually do this through ongoing discussions where I usually ask students if they're having troubles with assembling whatever that they have to assemble at home…" (TEMD01)* *"… athen in terms of like uh the actual demonstration we might say that there is a limit to the actual demonstration…I think WhatsApp uh it gives you uh that flexibility to actually hold such discussions because now um it's not even face-to-face" (TEMLD02)* *"We are doing things online to be honest it really made it difficult to demonstrate anything… I don't have a particular strategy that I can say but it is where you ask a question and then you let them discuss hence, we are using an online thing you just let them send through their response on a particular question or on whatever they see or notice during the practical and you let them discuss" (TENMLD01)*

In addition to discussions during the practical works sessions, teacher educators reported that they encouraged collaborative learning amongst preservice teachers. Findings reveal that collaborative learning approach was encouraged in response to materials access challenges especially for those who stayed far from school.

Lecturer's response

“The challenge was those students who were not around campus when they say they don't even materials it was a bit difficult to say how do we then go about this but one recommendation we had made was that they collaborate …” (TEL01)
Lab demonstrators’ responses *“I usually work with a problem-based approach and collaborative learning. the reason why I speak of collaborative learning is because mostly I usually try, I need to engage them in collaborating with their colleagues or their peers within the WhatsApp platform.” (TEMLD01)* *“…so that is the only way you put the question and let them discuss so that it not be teacher centred way of teaching” (TENM01)*

5.1.2.3 The learning approaches to physics practical work

Learning approaches refers to various ways in which preservice teachers had to engage with the given practical work activities for learning as intended by the teacher educators. Even though organisational or administrative strategies were properly put in place for learning to occur as presented in the above section, the designed and implemented practical was not strictly or rigidly structured or directed. The kitchen table practical work was rather flexible with teacher educators having less control over the learning process and the preservice teachers were at liberty to direct their own learning. The analysis of both teacher educators and preservice teachers’ interviews suggest that learning was rather students centred and student driven in a sense that discussions would happen only when preservice teachers asked questions or responded to questions in the WhatsApp group. The teacher educators had little control over the learning process that is they had little control on how preservice teacher would engage with the practical work activities. Preservice teachers stated that they only asked questions in the WhatsApp groups when they wanted clarity or to confirm something with the what they are busy with. When asked about how the learning was mediated during the practical work session teacher educators and preservice teachers said:

Preservice teachers’ responses *“I'm not sure others but on my side most of the time I would do the practical myself and only engage with a tutor if I find the question on the question paper like a bit confusing. But when it comes to the procedure of doing a practical itself we wouldn't engage in it like say that OK step one everybody is doing this, step two everybody is doing that no we wouldn't do that because sometimes others would do the practical in different times like myself I would do the practical, because the practical sheet would be posted even before the day of the practical”. (ST01)* *“The only difference with the practicals is that we had to conduct them ourselves so that was the part that was interesting” (ST03)*
Lab demonstrators’ responses

"… So, I usually come in if they are finding themselves with challenges in understanding instructions that they have to follow or challenges in terms of understanding the write up of the practical lab report it self... So, what happens is that the students are the ones who usually you know put in too much work and assemble everything that they have to do …I don't get involved in the event of demonstrating for the students" (TEMLD01)

Lecturer's response

"… I'm only guided by what students say on those WhatsApp platforms that they were using for pracs so if students are not saying much if they're not asking so many questions then I don't get to see whether they understand or not as far as the process is concerned with the pracs, which is a big difference if you had to compare it with the physical pracs because in the I would walk into the lab see how students are doing things and see if they're following the right processes if not and then try to redirect them and ask them questions they are doing the prac …" (TEL01)

Additionally, preservice teachers also stated that teacher educators encouraged collaborative work when connecting materials especially for students who did not have materials. However, the that to them was just a suggestion and they were at liberty to choose whether they take it or not. Two of the preservice teachers preferred to work alone instead of collaborating with others. The one prospect teacher stated that she tried to work with a group of students from her lab group in one practical work activity but it was chaotic with everyone trying to give input as it was huge group of students trying to input toward getting the connection right. She added that the collaboration rather worked well when she was just working with one another student after they failed as big group. Preservice teachers had the following to say about collaborative learning for the designed practical work activities:

Preservice teachers' responses

"… we submit the final report individually not a group but others did the practicals in groups but I always prefer to do it alone so that I can better understand or I can get what is that I'm supposed to learn from that practical, because especially when we are at home there are people who would just depend on you and they won't study before they can conduct that practical. "(ST03)

"uhm yes in some practical whereby I saw that actually this one is really impossible to work alone like I did call people in so that we can do the practical together … in the first incident like it was really a mess because when we're doing it somebody would say no this is what the instruction is saying the other one would say no the instruction is actually saying this. So sometimes we would get frustrated together …, we were like many about half a class. Where we were doing practical together and at the end of the day, we didn't find the things that we're looking for… and were left only with two people and then we ended up doing the practical ourselves and then got the readings that we were looking for." (ST01)

Lastly what emerges from the analysis is that preservice teachers relied on digital tools to search for guidance to understand how to manipulate with the materials and engage with it to apply and gain the scientific enquiry skills and construct scientific knowledge. Preservice teachers relied on YouTube and Google to guide their procedural and conceptual understanding alongside working with the practical work manual. When asked about the resources they use to help in completing the practical work preservice teachers responded as follows:

Preservice teachers' responses
"Okay most of the time I would use YouTube and also Google… before I even start engaging with the practical saerch for similar practical that somebody might have done. So, it will actually be a pre-lab…" (ST01)

In closing the section, the chosen practical work was kitchen table practical work which had the students hands-on with simple materials in their respective homes. The teacher educators wanted students to build an understanding of the scientific concept they taught in the lecture sessions. Moreover, teacher educators had less control over learning of practical work given under the remote learning conditions. Lab demis facilitated discussions if students were willing to participates. In their learning approach students preferred to also use of digital tools such as google and YouTube to guide their understanding of the processes and knowledge of enquiry. was common across the two data sources and it came out as one of the key themes and written in full in the next session as well.

5.2. The use of digital technologies and resources for teaching and learning practical work.

Teaching and learning practices in the remote context had the teacher educators and preservice teachers find different things and ways to help them to manage teaching and learning of practical work. Commonly across the participants and the practical work manuals emerge the use of digital technologies as the main resources to drive teaching and learning of practical work. As per analysis of the practical work manuals and the design team interviews, digital technologies were meant to administer teaching and learning. However, they ended up being the main contributing factors influencing teaching and learning. The design team implied that preservice teachers had to use digital devices and digital tools to connect on the learning platform, access and submit their tasks through the University Learning Management System. However, it appears from the analysis of preservice teachers' and lab demonstrators' interviews that digital technologies were used more than just for administrative purposes and they were central to facilitation and learning of the implemented practical work activities. This section presents the use of digital devices and tools to support teaching and learning as per the findings. The study found that both preservice teachers and lab demis mainly consulted digital technologies alongside other resources to enhance the teaching and learning process. The findings from all the participants are presented in sub-sections to follow.

5.2.1. Learning practical work through the use of digital technologies

According to findings presented in section 5.2, learning occurred remotely where all parties had to at least have one smart device to allow them have access to the internet and two main learning platforms and other digital tools MS Office, ULMS, and WhatsApp mainly for learning administration. The findings in the above section also reveals that the design team implied the use of the practical work manuals to guide the "At home practical work/kitchen table practical work" with the use of simple accessible material with strategies on how to use them to achieve the intended learning objectives. However, preservice teachers consulted various digital tools to assist themselves in achieving the intended learning objectives. Below I present the device and tools used for learning practical work all together.

5.2.1.1. Use of digital devices for learning practical work

In the remote teaching and learning context, online platforms were one way of keeping the people connected and smart devices or gadgets were the primary resources that preservice teachers needed to have to first access the internet and then connect to access the practical work manuals, any other information they needed, teacher educators and even to access fellow teachers in training. From the participants' interview analysis, three main smart gadgets emerge and those are Laptop, Smart Phone and Desktop. Table 13 below display the different gadgets that emerged from the analysis, highlighting specifically the ones that preservice teachers had access to and also used as their learning aids.

Table 13: Digital devices used by preservice teachers for learning

Participants	Laptop	Smart phone	Desktop
ST01	★	★	X
ST02	X	★	X
ST03	★	★	X

The preservice teachers had varying learning conditions in that they all did not have same privileges of accessing same devices. From table 13 above, the analysis reveals that two of the preservice teachers had access to both smart phones and laptops while the other had access to just the smart phone. Even the two preservice teacher had access to both, the report using laptops for learning while the other reported that she relied only on her smart to access all the other learning resources that internet access for their context. When asked about the device used for learning preservice teachers reported:

> *"I used my cell phone because my laptop crashed, and I've been relying on my cell phone … so I used my cell phone 24/7" (ST02)*
>
> *"I would say that my laptop did help me a lot when it comes to practical because sometimes when I didn't understand something I was able to go to the Internet" (ST01)*

5.2.1.2. Use of digital tools for learning practical work

Analysis reveals with the use of smart devices, emerges various digital tools that were key factors for connection and communication amongst teacher educators and preservice teacher, enhancing preservice teachers' understanding of scientific knowledge and processes and mediating learning all together. Table 14 below display different digital tools preservice teachers used to assist their learning of practical work. The analysis process took a form of taking out initial codes as described by preservice teacher in the different times of the interviews. The column headings in table 14 below are codes that emerged more/less frequently in each transcript and for each transcript, paragraph sentence lines are numbered using line number function on MS Word to identify position in transcript where the codes emerged.

Table 14: Preservice teachers' use of digital tools for learning practical work.

Participants	**Use of YouTube videos pre-practical task**	**Use of YouTube for conceptual understanding and visualisation**	**Use of Simulations for conceptual understanding and visualisation**	**Random google search to enhance learning for conceptual understanding**	**Use of ULMS, Teams and WhatsApp for learning practical work**
ST01	241-247	42-45; 269-273; 239; 241-247	n/a	42-45; 249-253	64-71; 104-110; 114-122
ST02	158-163	158-163	112-116; 150-152	165-168	69-72; 127-130
ST03	n/a	178-181; 189-193; 195-196	95-98; 102-108; 123-140	178-181; 183-184	74-80

From the interviews, preservice teacher used different tools for learning practical work and table 14 present all the different tools used. Analysis suggest that the preservice teachers use different digital tools for different reasons in their learning process. The types of digital tools used can be divided into two categories, that is the learning administrating tools and the subject/content learning tools. For subject learning tools, preservice teachers reported that they use YouTube videos, Simulations and Google search engine to enhance their science conceptual understanding and understanding of the procedure for improved scientific inquiry and practical skills. It is found that even though the three digital tools are used, YouTube videos and Google search engine are commonly used across all three preservice teachers. The analysis suggests that visualisation of scientific concepts and the actual procedure of connecting or manipulating materials was critical for the preservice teachers. Preservice teacher reported that they used YouTube videos and PhET simulations as pre-lab exercises to visualised the concepts and also see all the steps they had to follow to accurately connect the materials and also understand what they were supposed to do. For learning administering tools, preservice teachers reported the use of MS TEAMS, WhatsApp and ULMS for learning. It is found that these tools are mainly used for connecting and communicating with teacher educators and fellow classmates. These digital tools were mainly setup for teaching and learning were preservice teachers can access all the specific information and materials they needed primarily to start working on practical work. ULMS were used to access the practical work manuals in particular and all three administering tools where used to get more other information from either their teacher educators or fellow classmates. Preservice teachers shared the following statements about their used digital tools:

"So, if there is something that we need to do, I normally used the PhET simulations and I found others also online when we're doing a simple harmonic motion. So, they really helped in trying to understand simple harmonic motion … also I was not sure about the angles that I measured so I went to that simulation and tried to understand the different parts of the pendulum and how it works so yeah it made it clear" (ST03)

".... I would go to YouTube first because I know that somehow somewhere there is something similar that someone has done and after I will also go to Google …". (ST02)

"… for YouTube I would use it before I even start engaging with the practical search for similar practical that somebody might get done. So, it will actually be a is it a pre-lab, so that I would watch it and see how they do it and then I would also do it myself following the instruction on the practical manual. So, the videos would give me a context on what exactly my practical supposed to look like even though I have a picture as in the manual they would show us a picture of what my whole structure should look like …" (ST01)

5.2.2. Teaching practical work through use of digital technologies

Under the remote teaching and learning conditions, digital technologies are central to the processes. Teaching in particular also means choosing or prescribing the types of digital technologies for use in both processes and in the above sub-section it was suggested that preservice teachers at most had access to two kind of devices and used various kinds off digital tools to help them learn. Generally same devices were used for teaching; however, the design team and the facilitation team used different tools to inform their subject or content teaching. This subsection present findings of the digital technologies' teacher educators used to for teaching practical work in this case study

5.2.2.1. Use of digital devices for teaching practical work

Key to remote learning, is connecting to the internet and digital devices are rather critical for that initial purpose. Table 15 below, present the different devices used by teacher educators.

Table 15:Digital devices used by teacher educators for teaching practical work

Participants	Laptop	Smart phone	Desktop	Scanner
TELO1	★	★	X	X
TEC01	★	★	X	★
TEMLD01	★	★	★	X
TEMLD02	★	★	X	X
TENMLD01	★	★	X	X

The findings suggest that laptops and smart phones were common and key devices used by teacher educators to access the internet. It appears that these devices were used under different conditions, one lab demi stated that sometimes she had to use the desktop on campus at time when she had load shedding where she stayed and the consultant mentioned having to use scanners every now and then as he had to draw some illustrations on paper and transfer to his computer system using a scanner. When asked about the devices he had to use to help him design the practical work manuals, the consultants reported:

> *"The devices was just a laptop and a scanner to do some of the illustrations" (TEC01)*

5.2.2.2. Use of digital tools for teaching practical work

Analysis reveals with the use of smart devices, emerges various digital tools that were key factors for administering learning, enhancing lab demis' understanding of scientific knowledge and processes and really helping to respond to some of the conceptual clarity seeking questions from the preservice teachers. Table 16 below display different digital tools teachers used for teaching the practical work. The analysis process took a form of taking out initial codes as described by preservice teacher in the different times of the interviews. The column headings in table 15 below are codes that emerged more/less frequently in each transcript and for each transcript, paragraph sentence lines are numbered using line number function on MS Word to identify position in transcript where the codes emerged.

Table 16: Teacher educators' use of digital technologies and other resources for teaching practical work.

Participants	**Use of YouTube for pre-practical facilitation**	**Use of YouTube for conceptual understanding and visualisation**	**Random google search to enhance teaching**	**Use of ULMS, Microsoft Office, Pdf and WhatsApp for teaching practical work**	**Other resources used for teaching practical work (Hardcopy Textbooks)**
TEL01	n/a	n/a	n/a	n/a	129-136
TEC01	n/a	n/a	n/a	87-90; 179-181; 67-69;174-177;191-193	92-93; 95; 98-102
TEMLD01	n/a	n/a	178-180; 197-212; 21-23	51-55; 97-100; 135-137; 86-95; 162-169; 25-27	n/a
TEMLD02	n/a	n/a	285-289; 292-299; 303-309; 312-313; 278-281; 381-386	21-23; 25-27; 29-34; 116-128; 405-409; 132-133; 136-141; 130; 78-87	n/a
TENMLD01	166-168	169-173; 182-185	166-168; 169-173; 182-185	131-136; 34-35; 101-102; 50-52;	n/a

From the analysis teacher educators emphasised the use of digital tools for administering learning at most. They mention use of ULMS, MS Words, Pdf and WhatsApp for administering the teaching of practical work. The consultant mentions that they would upload both MS Word and Pdf document versions of the practical work manual for preservice teachers to access on the ULMS, and lab demis stated that they access the actual manuals and submitted practical work scripts on the ULMS for assessment and feedback. Lab demis also report that the WhatsApp platform is used for facilitation where they run Q&A driven discussions with the preservice teachers. Of great notice in the above table is the different resources use for teacher educators' conceptual understanding. With their teacher professional judgement, lab demis stated that they do a google search to access scientific content to enhance their conceptual understanding. The one lab demi also state the use of YouTube Videos to prepare for the facilitation of practical work. The design team on the other hand did not prefer use of digital tools to access subject content. The design team report that they used hardcopy text books to engage with the physics subject content. When asked about the digital tools they used to inform their teaching strategies and practices, teachers educators reported:

" … I do use a website such as like a library text sometimes I do use that because I found it to be reliable and then also use like sites such as lumen learning so I'll say those two are the sites that maybe guide my content if I want to look for more because as a teacher you need to like to know more so if I need to know more about content other than what's included in the lecture slides I do at times go to those sites and to actually like get to see much of the content explaining in details" (TEMLD02) *"I would like to say Google is my best friend because I usually use Google to extend the knowledge that is on the worksheet which are provided by the lecturers you know if I feel like the lecturers provided us with inadequate knowledge then I go to Google just to extend that or to clarify certain things for the students as well". (TEMLD01)* *"…Most of the time I had to go to watch YouTube most of the time and also Google some things so that I can be able to answer any questions that they ask …" (TENMLD01)*
Non-use of digital tools *"So, we use the textbook to deal with the practical work that we were doing, and that practical work was aligned with the content that was being taught so we used the textbook and also relying on the experience of the expect that was assisting in the process". (TEL01)* *"… some of the books that I used are very old and they've got really good ideas in them … it's textbooks which I had at university … and one book that is actually very useful it's called string and sticky tape experiments …" (TEC01)*

5.2.3. The teaching and learning of practical work.

The use of digital technologies and other forms of technologies varies across the three stake holders, but more so the use of digital tool than devices. Figure 22 below summarise teacher educators and preservice teachers' use of digital technologies and other resources for teaching and learning practical work.

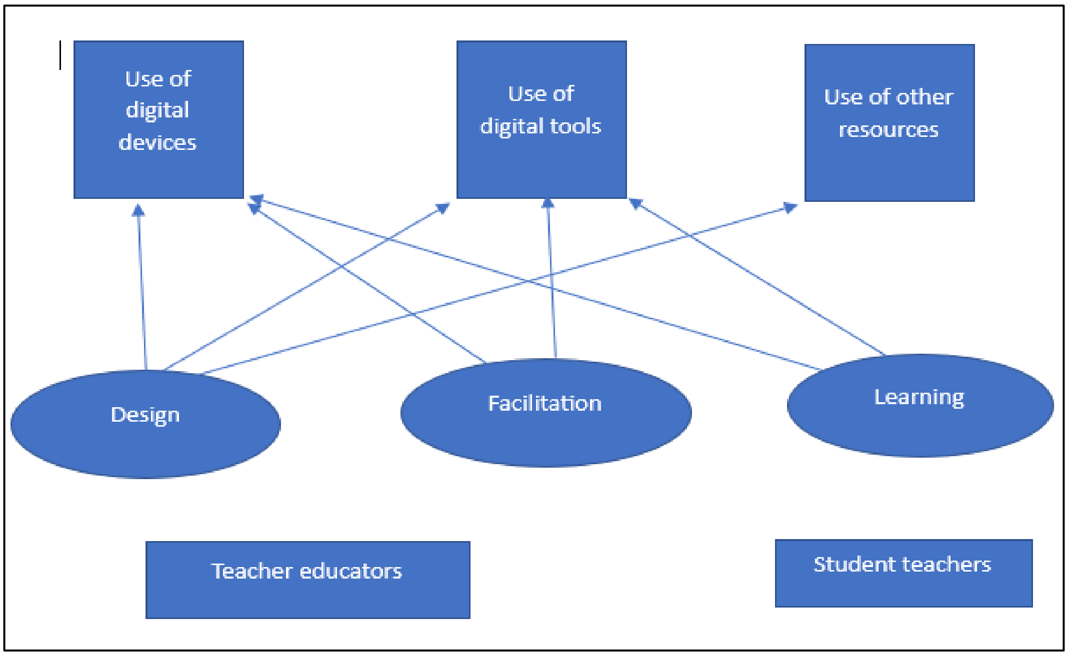


Figure 17: Summary of teacher educators and student teachers' use of various resources for teaching and learning practical work.

The three interviewed stakeholders hold different responsibilities to the whole process of teaching and learning practical work, even the teacher educators as a group constitute different role players, that is the design team and the facilitation team, as such the use digital technologies varies accordingly. What is common amongst the participants is that they all relied on digital technologies one way or the other in their different roles. The difference amongst the stakeholder groups is that the design also relied more on non-digital resources such as hardcopy textbooks to source out information that helped guide their science conceptual understanding. The facilitation and learning team on the other hand relied only on digital technologies for both conceptual understanding and administrative purposes. The lecturer who is part of the designed stated that he had hoped that the preservice teachers do not run to internet or google based information for guidance, however the preservice teachers found much more comfort in consulting the internet in all stages of their practical work learning process.

"… we did not want students to just go on Google and find answers to the prac you know. So, we wanted them to actually construct these things and get the answers from the materials that they have worked with. So, we wanted them to have that life experience with the practicals that they were given. So, we did not want them to just go on Google or to the Internet and get the answers to the pracs that we were giving them." (TEL01)

5.3. Experiences of teaching and learning the practical work.

The different stakeholders interview reflects on the different experiences they have had with practical work and the various factors that really influenced their teaching and learning processes including actions and choices taken under the remote conditions. The remote learning conditions were influenced by the lock down regulations which had institutions making a shift in context, learning and teaching approaches (Moloi & Mhlanga, 2020; Robinson & Rusznyak, 2020; Glietenberg, et. al, 2022). The findings in section 5.2 and 5.3 has shown that indeed teacher educators had altered their pedagogical strategies and practices which also impacted so much on learning. Both teacher educators and preservice teachers reflects that they had to rethink their approach to teaching and learning practical work in response to the new learning conditions in their institution. All stakeholders experienced both teaching and learning opportunities and limitations in their processes and practices under the circumstances. The sub-section presents the experiences and factors influencing teaching and learning of practical work. The experiences and factors are reflected as opportunities and limitations as per participants interviews. Overall findings indicate that both teacher educators and students were limited in one way or the other by the context of teaching and learning practical work. However, there was also opportunities for creativity and a room for learning new things. This was most especially for preservice teachers and the design team than the facilitation team. The lab demis were more disadvantaged than advantaged as they were not able to be of great support to students, that is they were not able to demonstrate to guide students in doing the practical work.

5.3.1. Learning practical work.

Learning practical work in the remote learning setting was experienced differently by preservice teachers due to their different contextual factors. While the preservice teachers were used to doing practical on campus having the experience of physical laboratory work in what they describe as the "scientific context", they then found themselves having to do practical on their own in their respective residences/homes out of the scientific context using the not so scientific materials to conduct their practical work. This sub-section presents the challenges and opportunities faced by the preservice teachers in learning practical work.

5.3.1.1. Limitations to learning practical work

Analysis of preservice teachers' interviews reveals that learning was not as smooth as intended in the design, there were rather challenges and limitations experienced by preservice teachers in using the practical work manuals and in learning the practical work altogether that emerged on the ground. Preservice teacher rather faced a few limitations experienced differently and in different levels due to each preservice teachers' learning context. Table 17 indicate some key limitations that emerged from the interview data as expressed by preservice teachers.

Table 17: Limitations to learning practical work.

Participants	Limited knowledge management strategies and practices	Challenges with Simple accessible materials	Internet Connection problems	Technical glitches	Working independently	Geographical location	Overlooked aspects from the practical work design
ST01	75-78; 206-211; 314-327; 223-235; 213-219; 311-312; 256-260; 263-266	148-152; 15-17; 19-24	64-71	64-71;	19-24; 75-78; 213-219;	148-152	314- 327; 336-341; 276-283
ST02	53-66	53-66; 182-188; 191-196; 199-201; 210-213	85-88; 92-95;	69-72; 92-95	127-130; 144-147	85-88; 215-219	199-201; 191-196; 182-188
ST03	74-80; 144-156; 267-283; 348-350; 202-218; 224-236; 334-344	102-108; 123-140; 224-136; 239-245; 247-256	55-57	55-57; 61-66	267-283	224-236	267-283

From table 17, there are seven factors that emerged as limitations or obstacles to learning practical work and these are; Limited knowledge management strategies and practices by teacher educations or rather less intervention or mediation by teacher educators, limited or inaccessible Simple Materials, Internet connections problems, Technical glitches, Independent working mode, geographical location and some aspects of practical work overlooked by the design. Of great importance is to highlight that these limitations were directly or indirectly experienced by the preservice teachers. Of all seven limitations key are limited knowledge management strategies and limited access to the prescribe simple materials. All three preservice teachers were mostly affected by limited knowledge management strategies and interventions by the teacher educators. Preservice teachers stated that there was less learning support from teacher educators and at most the implemented practices during the practical work sessions were rather not effective. Preservice teachers stated that there was less engagement in the WhatsApp groups and that hindered them from actually understanding the content as sometimes they would remain with their misconceptions as they would not get the desired clarity from Lab demonstrators in particular. Preservice teachers also expressed experiencing challenges with the prescribed materials in one way or the other. Two out the three did not have access at all to the materials and have had to improvise with some materials alongside use of digital tools to assist them in the process, the last one though had full access to the materials as prescribed by the design. Even though, she had access to prescribed materials as a class representative she reported having to work with fellow classmates to accommodate those who did not have access to materials. The following excepts were extracted from the interview transcripts as voiced out by the preservice teachers:

Challenges with accessing the prescribed materials

"I mean it was a different one I was trying to understand like for example the pendulum I was trying to understand what affects it speed and all of that, because I found it difficult conceptualizing it just from studying the notes. so, I wanted to see it happening, so we did it also with the practical but the materials I was using was not so as prescribed, the string that I was using was too thin so I wasn't sure on what effects it has, also was not sure about the angles that I measured …" (ST03)

"yes, there was that challenge, but then I tried to find materials. We had one where we had to use a rubber I mean the elastic band so I used those mask elastic bands see from the surgical masks OK I had to improvise using that band ..." (ST02)

"OK because myself I was the classroom representative I was getting a lot of queries from students, most of the were complaining about materials, even though they did offer materials but others who lived far away from school were asking how can we get and now they're expected to improvise and use whatever that is available to them …" (ST01)

Limited support or mediation from the lab demonstrators

"… just learning online even if you have a misconception sometimes you don't find out about it because you don't have conversations with other students and also the lectures or the tutors so yeah even if I have a misconception, I remain with it …" (ST03)

"Yes, we had tutors on WhatsApp, and we were divided into groups. So, if we had any question or you are confused, don't understand instructions you ask the tutors, but it wasn't effective" (STO3)

"To be honest, for me I think having a Tutor online is not really that helpful because now you're on your own and sometimes you ask them questions and they don't really answer you directly. they will help when you asked am I on the right track or something OK am I using the right formula if I'm using this one yes, they would answer those kinds of things but most of the time we would do the practicals on our own … they were not really that effective." (ST01)

The two preservice teachers reported that they had to further improvise and mentioned that they had difficulties with observation as they were manipulating the materials. In their use of the improvised materials, they stated that could not see some of the concept quite well from what they were taught in the lecture session. The following excepts are from ST03 explaining the effect of using improvised materials for practical work.

"I mean it was a different one I was trying to understand like for example the pendulum I was trying to understand what affects it speed ... so I wanted to see it happening, so we did it also with the practical but the materials I was using was not so as prescribed, the string that I was using was too thin so I wasn't sure on what effects it has, also was not sure about the angles that I measured …(ST03)"

"it was like we had to find an inelastic string for example for the practical of the pendulum and then also just a heavy object that you tie at one end of the string and then have a table which is at a certain height above the ground then you can just hang the string and then just make a simple pendulum from that. The angle I don't remember what we were supposed to use to measure the angle but I used a protractor to measure the vertical angle but I saw that there is a lot of friction and I think it was higher than it was supposed to be … (ST03) "

"…. so when I was doing it I could see that OK there's a change if the string gets too long and there will be a change in the speed of the pendulum but if it gets too short then there will be a change then but since from the content we are told that OK simple pendulum will just move on in that harmonic Motion forever with without stopping. so, in reality for us here at some point it will stop because of friction." (ST03)

5.3.1.2. Opportunities to learning practical work

Even though there were limitations or not so favourable experiences with learning practical as highlighted in the above section, all was not as bad. Preservice teachers relay some opportunities or good experiences with learning the designed practical work under the conditions. Preservice teachers generally found doing practical work at home interesting, as they believe that being hands-on in practical work remains important. Preservice teachers found that Good internet connection, the flexible nature of the working conditions, availability of materials and teacher educators' availability for inquiry were quite helpful for their learning processes. Table 18 below highlight some of the learning opportunities found in the designed practical work.

Table 18: Students' opportunities to learning practical work.

Participants	Good internet connection	Tutors and lecturers' availability for inquiry	Flexibility/ Student centredness working mode	Possible Creativity or innovation	Availability of materials

ST01	60	213-219; 206-211;269-273; 114-122; 104-110	114-122; 15-17	n/a	154-158
ST02	n/a	178-179; 144-147; 41-49; 172-175; 133-137	127-130	53-66; 182-188; 191-196; 199-201	n/a
ST03	38-39; 51	321-329; 74-80	154-156	300-315 154-156	334-344;

From table 18 above preservice teachers reflect on five main factors that they saw as opportunities for their learning process. All three preservice teachers reflect that the fact that they had the educators available when they want to inquire was an opportunity for the get clarity as they were doing the work. The preservice teachers also see the learning opportunity in the flexible nature of how the practical work was rolled out. They all report that having the allocated time to work alone on the practical work was helpful, as it gave them time and space to pace their own work. Students also commended the design of the practical work on the nature of materials prescribed for use. Students report that though they did not have the right and prescribed materials, but they improvised with materials to be able to engage with the practical work as designed, which allows for creativity and innovation reflecting on the realities in South African Schools. From the three preservice teachers, two reported that they did not experience any internet connection problems and that for them allowed continued learning without any particular problem for the practical work, and good internet connection proved to impact positively on learning as the one prospect teacher who had internet challenges reported having to miss some of the sessions which she had to go through some of the notes by herself. Extract from the preservice teachers' interview about some of the learning opportunities are presented below.

Good internet connection

"As long as like there's network and this year, I was living on campus, so I had no issues with data or network is just working fine" (ST03)

"Where I live it was 10 out of 10, I didn't have any internet problems" (ST01)

Teacher educators' available for inquiry

"We had our Demies, … with regards to two practical work they were there if one wanted to ask, they were just a WhatsApp away. so, it actually depended on how one felt with regards to reaching out" (ST02)

"…I'm not sure others but on my side most of the time I would do the practical myself and only engage with a tutor if I find the question on the question paper like a bit confusing…" (ST01)

Flexible nature of the learning conditions

"Yeah, same thing, the only difference with the practical is that we had to conduct them ourselves so that was the part that was interesting" (ST03)

"sometimes others would do the practical in different times like myself I would do the practical, because the practical sheet would be posted even before the day of the practical so most of the time I would maybe a day or two I would do the practical myself and see if I can do it and then on the actual day of the practical on the slot that is given in the timetable I would actually do the actually do the practical and start answering questions" (ST01)

Room to be creative and innovative

"sometimes you have to compromise like the one for pendulum the string that I used was not the one that was recommended so I had to compromise and just find a string that was inelastic that could maybe do the job but it won't do the job as the one that was recommended from the instructions so most of us I believe we compromised if you are unable to find where you can buy the straws then maybe you will just try to find them on the streets and sometimes you get them the length of the straws are not the same so that will affect the motion of the wave that you'll be creative and all of that" (ST03)

"Yes, there was that challenge, but then I tried to find materials. We had one where we had to use a rubber, I mean the elastic band, so I used those mask elastic bands see from the surgical masks" (ST02)

5.3.2. Teaching practical work

Teaching practical work under the remote conditions took the teacher educators out of their comfort zones, the have had to rethink the design and the teaching practices altogether and in the process experienced some limitations and opportunities as well. Teacher educators at most experienced similar limitations and opportunities to the same degree or level even though they were located in different places around Gauteng province. This subsection presents the limitations and opportunities experience as expressed by the teacher educators during the interviews.

5.3.2.1. Limitations to teaching practical work

Teacher educators experienced some limitations in their teaching of practical work. The limitations were mostly experience during the implementation phase more than the design phase. The reflected limitations are concerned with the actual teaching practices during the different practical work sessions that they had for implementation of the designed practical work. Teacher educators reveal about six factors that limited them in teaching the designed practical work. The reflected limitations are uncertainties with what preservice teachers are doing with the designed practical work, limitations to knowledge management strategies and practices, Technical glitches, Internet connection problems, WhatsApp as a learning platform and Geographical location. Table 19 below present the reflected limitations and where they are reflected in the different interview transcripts of the teacher educators.

Table 19: Limitations to teaching practical work.

Participants	Uncertainties	Limitations to knowledge management practices	Technical glitches	Internet connectivity problems	WhatsApp learning platform	Geographical location
TEL01	343-354; 245-266; 146-150; 343-354	71-90; 271-286; 152-166; 245-266; 314-329; 146-150	55-63	33-34; 36-40; 43-47-50-55	71-90	36-40; 43-47
TEC01	n/a	196-206; 285-290	55-63	220-229	n/a	n/a
TEMLD01	86-95	68-79; 197-212; 225-236; 225-236; 162-169; 162-169	n/a	45-49; 57-63; 32; 40-43; 197-212; 252-260	86-95	40-43
TEMLD02	438-44; 360-379; 419-431; 438-444	153-163; 390-403; 360-379; 415-417; 419-431; 98-110; 54-63	73-87; 98-110; 438-444	54-63; 90-95; 360-379; 438-444; 319-321; 342-345; 98-110;	73-87	73-87; 90-95
TENMLD01	149-157	77-82; 149-157; 224-239; 240-244; 85-91; 271-277; 319-324	131-136	44-47; 131-136	203-212	n/a

From table 19 above the teacher educators generally found themselves restricted in how to approach and manage the learning processes. Lab demonstrators in particular state that they found using WhatsApp as a platform to facilitate practical work session was limiting in they were just limited to just having to drive learning though discussions only. They believe that the platform limited them in knowledge management strategies and practices, in that they could not even demonstrate the practical work activities for the preservice teachers. The lecturer on the other hand reported that he was limited to just observing discussions and conversations as they happened in the different practical work groups and had no moment or opportunity to intervene or be part of the conversation. Bad internet connection emerges as the second common factor that badly affected the teaching of practical work, this factor was mostly associated with one’s geographical location or load shedding challenges in their places. The lecturer reported having to move to campus always so to avoid disruptions and lab demonstrators report having to be late or absent altogether from the sessions when they are experience bad signal. Moreover, all the teacher educators except the consultant reported that they are mostly uncertain if learning of practical work is really taking as they envisioned in the design. It is reported that preservice teacher directed their own learning, that is they had to rely first on the practical work manual and follow all the instructions and learn the intended scientific concept, then ask questions of clarity in the WhatsApp groups and at most they were not as engaging in the groups. Teacher educators were left with no choice but to just trust that preservice teachers are engaging with the practical work manual as intended. The follow excepts were extracted from the interview transcripts for the emerging limitations.

Limited knowledge management strategies

"… in terms of like uh the actual demonstration we might say that there is a limit to the actual demonstration but because what we do we just show them the practical that they need to do but then since it's online and we using WhatsApp platform it's only text so there is no part where we actually like demonstrate" (TEMLD02)

"…first of all I'll start by acknowledging the fact that using WhatsApp as a platform for teaching or demonstrations during the practical activity you know has its limitations … when it comes to constraints there are many of those firstly is the issue of you know physical demonstrations you know I just feel like online learning just takes away that aspect of being involved in the practical activity ..." (TEMLD01)

"… simply because learners are hiding behind the screens there's really not much that I can do if they choose not to participate ..." (TEMLD01)

"…that's the disadvantage with the online because that's the only thing I can do and I'm only guided by what students say on those WhatsApp platforms … so if students are not saying much if they're not asking so many questions then I don't get to see whether they understand or not …" (TEL01)

Uncertainties

"… which I kind of explained earlier to say that sometimes you may find a situation where by you pose a question to the students and they don't even bother responding…" (TELMD01)

"I would say that there are constraints, in as much as we are conducting a practical work session you cannot ensure that everyone is present in that session, in a way that you will find that you facilitating a session but then in that session you are maybe with three students out of 25 students …" (TEMLD02)

"…of course, the idea that you are not too sure whether or not students are effectively engaging with the practical work that you've given them of course they will be sharing their videos but not all of them share their videos so you are not so sure as to whether they were able to engage with it …" (TEL01)

Internet connectivity problems

"… moved around May I've moved into an area where the network is very much powerful… yes I can say that for me example I come from like a rural area so we found that there it's like the network can be bad at times depending on where you are in the region that you had like you encounter challenges even like in using like uh apps such as WhatsApp which do not require much of that network coverage but becomes problematic …" (TEMLD02)

"… the issue of network like I said earlier in certain situations rather where I find myself with load shedding it means that I'm in a position where I cannot facilitate the practical work therefore affecting things for the Learners as well..." (TEMLD01)

"Connectivity is poor where way I am so that becomes a problem at times when we have to conduct your lectures and other related teaching and learning processes" (TEL01)

5.3.2.2. Opportunities to teaching practical work

Even though they were mostly limited in their teaching of practical work, teacher educators also had some few experiences they consider opportunities for teaching practical work under the remote conditions. Teacher educators report about three factors that enabled them to still be able to facilitate or to teach the practical work even though it was not favourable to do so. Teacher educators reported that they mostly had a room to be creative and innovative in their approach both from design and facilitation perspective, the arranged partnership per lab group which allowed for collaboration amongst the colleagues and the open access to the different digital tools for information. Table 20 below presents three opportunities to teaching practical work under the remote conditions.

the report some opportunities to teaching practical work. Lab demis report that the collaboration that existed between themselves helped in insuring that teaching and learning occurs in the designated times because even if there would be network issues on one of the pair the other is available to ensure that students' queries are attended to. The lecturer report that the presence of the practical work expert and the lab demonstrator assisted in having the student teachers get engaged with the designed practical work. Table 17 below present the various opportunities to teaching practical work as per teacher educators' interviews.

Teacher educators, lab demis in particular saw an opportunity in having open access to information on the internet

Table 20: Opportunities to teaching practical work.

Participants	Having access to digital tools for information search	Creativity – the room to develop innovative teachers	Collaboration amongst colleagues
TEL01	n/a	92-100; 102-11; 138-143; 245-266	71-90; 129-136
TEC01	n/a	131-142; 73-84;158-172	21-28; 40-45
TEMLD01	197-212	n/a	58-63;
TEMLD02	153-163; 360-379	153-163; 172-186	116-128; 335-338; 348-351
TENMLD01	169-173	224-237	56-60; 94-99

Across the five and with their different roles, teacher educators believed that the provided arrangement or opportunity to work together and in collaboration amongst themselves really allowed for the teaching of practical work to continue regardless of whatever conditions they found themselves in at any point in time. From the analysis, the design team worked hands in hands and expertise of both the lecturer and the consultant in producing the complete practical work manuals. And the facilitation on the other hand used the partnership option very well when they found themselves in unfavourable conditions for facilitating the practical work sessions. The collaboration was mostly helpful for lab demis as they were able to hold the fort for each when one was facing either technical glitches or connectivity issues. Which at times their efforts are met by assistance of the lecturer during briefing or debriefing sessions in the lectures. The design team viewed the contextual changes to teaching and learning as a way to be creative and think of something they have never done before, and they saw this as an opportunity to develop innovative teachers who are going to be resilient and confident in conducting practical work in the South African public schools' context. Moreover, the lab demis in particular saw the open access to the internet and the information using digital tools quite use for them during the facilitation. Lab demonstrators reported that they together with the preservice teachers were mostly at liberty to just do a google search for information to enhance and expand on their understanding of scientific concepts which enabled them to respond to conceptual queries from the preservice teachers. Below are excepts extracted from teacher educators' interview where they report opportunities or enabling factors for teaching the designed practical work.

Collaboration amongst colleagues:

Facilitation team

"the practical session does continue because as much as there is load shedding on my side, we are a group as laboratory demi as you find that students will seek UM help to other groups reach out to other groups and to actually get that sort of guidance …" (TEMLD02)

"What I can see is that most of the time when I'm not able to connect it's either … try to call my lab partner and then ask if he is able to get into WhatsApp and try to talk with the students … but that is the only way to do it because we are paired so it's easy to call someone else and ask …" (TENLMD01)

Design team

"Largely the syllabus that the lecturer was following he sent me his teaching program and so I matched the activities to what he was going to teach…" (TEC01)

"…So, with that then in mind so I had to work with the with the physics specialist you know someone with more experienced in this to create practicals …" (TEL01)

Access to google search

Facilitation team

"…one of the opportunities is that information is easily accessible for one if my students probably don't understand something chances are they are at a better position to just Google whatever and find information as easy as that…" (TEMLD01)

"… so, I would say that this part it is sort of yes it gives that freedom to students to actually sort of like search being searched for knowledge" (TEMLD02)

Opportunities to be creative with the design of teaching practical work

Design team

"… They are not getting experience of practical work in school so our graduates need to go out there able to organize and manage and teach with practical work and now the reality is of course that in schools is apparatus which half of is missing or it's locked up or it's just not used and so we want our graduates to have the confidence to say well I don't have the standard equipment to make a pendulum but with an orange and a piece of string and a cell phone stopwatch I can still do the pendulum activity. And so, we will have the grade 12 doing the pendulum activity and we are not going to be put off by the fact that the storeroom has been locked and someone lost the key" (TEC01)

"… OK we are training teachers and with or without Covid these teachers are supposed to go to schools and … the majority of our public schools and requires teachers to be present in the classroom it requires teachers to actually perform the practical with the students so it's important that our teachers who goes into the field they do have that practical aspect of the skills that are required to perform whatever practical that they have to perform. so, what I was doing then with

the students it was to give them that practical skill through the kitchen table pracs you know which is something that I don't think they would ordinarily get with your simulations and stuff …" (TEL01)

5.4. Factors affecting teaching and learning practical work.

Teaching and learning practical work under remote conditions presented both limitations and opportunities for all the participants. Both teacher educators and the preservice teachers faced quiet a number of limitations as compared to the opportunities in their teaching and learning processes respectively. Of great notice is that what seemed to be a limitation to one group was an opportunity for the other group in one way or the other, and some factors were viewed as limitations or opportunities by both parties. Some of the key findings that are common amongst all the interviewed stakeholders is that; firstly, learning was student centred in a sense that preservice teachers were limited in their knowledge management strategies and practices; secondly, All the participants were directly or indirectly affected by poor internet connection and technical glitches; and finally teacher educators' availability on the WhatsApp platform did not translate effectiveness, rather the employed facilitation approach was not effective. And unique to preservice teachers is that limited/No access to the prescribed simple materials is a disadvantage in that accuracy is compromised. The key findings are further deliberated subsections below.

5.4.1. Learner centredness

Teaching and learning practical work in this case proved to be student centred with teacher educators having limited control to how preservice teachers learnt the given practical work. Most of the work was left into students' hands with little mediation from either the lab demis or lecturer. Preservice teachers found this to be an opportunity to explore other avenues such as digital tools to enhance their scientific knowledge and be innovative by improvising with materials similar to the prescribed materials. Teacher educators mostly the lecturer and the lab demonstrators found this fact a disadvantage to their role as they could only be respondents to whatever preservice teachers raised. They reported that they were limited in a sense that they were very uncertain if preservice teachers were really engaging with the practical. Essentially teacher educators were unsure if learning was actually happening as they wanted it to. See excerpts extracted from the interview transcripts.

"unfortunately, there isn't much that you can do so you depend on student's participation" (TEL01)

"learners are hiding behind the screens there's really not much that I can do if they choose not to participate I wanted to say that usually because students are working from home" (TEMLD01)

"So, they gave us the instructions on what to do and the materials that we need so we conducted them ourselves and then we took pictures and some they wanted videos and then send them back, so it wasn't a problem" (ST03)

5.4.2. Poor internet connection and technical glitches

All the interviewed stakeholders reflected that they were directly or indirectly limited by poor internet connections and technical glitches. It can be happening to them directly or to the next person, mostly especially when it happens to teacher educators, the preservice teachers also get affected in one or the other. Teacher educators were more affected by the poor internet connection as compared to the preservice teachers and this effect can also be factored down to attributes such as load shedding and the geographic location from which one stays. Two of the preservice teachers on the other hand reflected that because they were situated in school residences they did not experience poor connections. However, indirectly when teacher educators were facing load shedding or general internet connection problems they would not be accessible to them at the time of the practical work session and that was a limitation to them in a sense that when that time elapse then it means that they are not going to get responses to their questions. Technical glitches on the other refers to mostly blockages or disruptions on the ULMS during the briefing and debriefing sessions with the lecturer. Also confirmed by the consultant and the lecturer, preservice teachers reported that the ULMS conference would not work at times or some of the features would stop work due to system failure sometimes and sometimes due to network disturbance and they would lose interest and be less enthusiastic when the system recovered. See excerpts extracted from the interview transcripts.

"well it has a great impact in a sense that let's say we are having a life session you are connected to the Internet so the moment you are disconnected definitely students will also lose some motivation so when you reconnect again it may be that you know some students have lost interest they are discouraged they've left the session ..." (TEL01)

"the energy decreases because … I was the platform it was working but, on my side, it was not allowing me to speak to ask questions so I had a question that I wanted to ask I needed a clarification but the lecturer could not hear me so that just discouraged me after" (ST03)

5.4.3. Teacher educators' availability vs Ineffective teaching approach

Preservice teacher saw the availability of teacher educators for support and assistance with their various queries regarding their learning process as an opportunity. However, they also mentioned that their approach to facilitating the sessions was rather not effective. Three of the preservice teachers mentioned that lab demis were easily reachable on the WhatsApp platform, however there were no engagements as such ineffective, as they would still go away from session with some conceptual misunderstandings. Lab demonstrators on the other confirms that their hands were tied as the WhatsApp platform used for facilitation restricted them to the employed approach. In this case they were just limited to discussion and if the preservice teachers were not willing participate then there would be none happening. Teacher educators stated that they were limited to only what the preservice teachers bring into the WhatsApp group and anything unspoken will go unresolved. See excerpts extracted from the interview transcripts.

> *"It's just not the same as having the tutors in face to face asking them questions, they take time to answer and even if I do ask a question because sometimes on WhatsApp you are just unable to ask it in the way that you want to ask it as you would do in person so I just felt they were not effective" (ST03)*
>
> *"for me I think having a Tutor online is not really that helpful because now you're on your own and sometimes you ask them questions and they don't really answer you directly. they will help when you asked am I on the right track or something OK am I using the right formula if I'm using this one … they were not really that effective" (ST01)*

5.4.4. Limited/No access to the simple materials

The preservice teachers were directly or indirectly affected by the limited or no access to the prescribed materials. This is one key limitation for the preservice teachers as it also preservice teachers had to rethink the use of the practical work manuals. Two of the preservice teachers stated that they had to be creative with materials by finding something closer to what is prescribed in the practical work manuals. The one other preservice teacher mentioned that even though she did not have any problems with accessing the materials, at some point they had to move to campus to collaborate with those who did not have materials. This act to some extends did not yield the desired results as the setting turned to be chaotic. The prospect teacher was indirectly affected by the fact that others in the class did not have materials as such she had to accommodate others or collaborate with others. This finding was backed up by the teacher educators whom stated that the only solution they had to combat the challenge was to suggest that those with materials collaborate with those without the materials and suggested that this can also be done remotely through video calls. See excerpts extracted from the interview transcripts.

> *"OK because myself I was the classroom representative I was getting a lot of queries from students, most of the were complaining about materials, …others who lived far away from school were asking how can we get and now they're expected to improvise and use whatever that is available to them in order for them to complete the same practical that we were completing with the exact material that was needed" (ST01)*
>
> *"sometimes you have to compromise like the one for pendulum the string that I used was not the one that was recommended so I had to compromise and just find a string that was inelastic that could maybe do the job but it won't do the job as the one that was recommended" (ST03)*
>
> *"I tried to find materials. We had one where we had to use a rubber I mean the elastic band so I used those mask elastic bands see from the surgical masks OK I had to improvise" (ST02)*

5.5. Chapter summary: summary of major findings

The teaching and learning of practical work were mainly directed through the practical work manuals which outlined the what needed to be known, what to do and how to do it to know what is intended. The findings reveal that the teaching of practical work intended for preservice teachers to be hands-on and practically connect simple materials in their respective environment to construct their own knowledge of the scientific concepts and gain some scientific enquiry skills. Moreover, the findings reveal that digital technologies, more especially the digital tools were central to facilitation and learning of the designed practical work. Lastly, it emerged that all participants had some limitations and opportunities to teaching and learning practical work under the remote conditions in one way or the other. Some of the experienced limitations and opportunities were common amongst the participants while others were unique to a specific stakeholder group, and even more interesting some limitations for the one stakeholder group seemed to be opportunities for the stakeholder group or vice versa.

Chapter 6: Discussion of findings and conclusion

6.1. Introduction

Teaching practices cannot be separated from learning practices as such the aims of teaching are experienced through learning. While teachers think, plan, and execute lessons, they should have in mind the students who are at the receiving end of the lessons or tasks. This study sought to explore and understand in detail the tailored teaching and learning of physics practical work to third year preservice teachers in the remote teaching and learning conditions. The main question asked by the study was: How does a South African University respond to physical science practical work in the remote teaching and learning context? To answer the main research question, the study was guided by the following sub-questions:

1. What is the nature of physics practical work taught and learned in a teacher education course?
2. What are the factors influencing the teaching and learning of physics practical work?
3. What are the physics teacher educators' and pre-service teachers' experiences of practical work designed for remote teaching and learning?

This chapter discuss the findings of the study presented in chapter 5 with the aim to answer the research questions asked in Chapter 1. As per chapter 3, this study used Mishra and Koehler (2006) TPACK and Vygotsky's (1978) ZPD as lenses to understanding teaching and learning of physics practical work in a teacher education course in the unprecedented remote teaching and learning context respectively. TPCK helped me in making sense of the overall teaching approach taken by all the teacher educators in the context where digital technologies were central to teaching and learning. It is important to still highlight that the aim of viewing the data from TPACK lenses was not confirm or confront or examine teacher educators' use of TPACK in teaching approach in any way. However, the aim was to understand the teaching strategies and practices where the technology knowledge component was inevitably central to the processes, to understand how the three knowledge products formed part of the teaching processes either interlinked or not. ZPD on the other hand helped with understanding how various tools were used to mediate learning of practical work during the time when students were working alone remotely in their respective places of residence away from the university laboratory context. The ZPD concept also allowed an understanding of the experiences of all participants, which is to understand the complexities of how all participants related to each other in having learning take place.

The chapter responds to the three research sub-question by discussing the findings presented in chapter. The findings presented the different ways in practical work was approached both in design and in implementation, revealing its nature holistically in how it was thought of, taught and learned including the factors affecting the teaching and learning and how it was experienced by all the participants in their varied teaching and learning environment. The chapter further present and discuss the recommendations that emanated from this exploratory story.

6.2. Teaching and learning approach to physics practical work.

In the remote teaching and learning context, one could wonder how teachers and students would approach science practical work, especially teachers and students who are in the business of training for pedagogical practices. Science practical work is historically known or associated with a very well-equipped laboratory where the magic of manipulating scientific apparatus to construct science knowledge or ideas happens (Solomon, 1980). History is continuous being updated and processes are forever redefined by the inevitable change and evolution whether human induced or nature induced. Off recent centuries and really in the current times science practical work has evolved in how and where it is done. Digital technologies are at the centre of responsive transformation to rising potential problems, enforcing innovation, flexibility, adaptability and creative thinking as key skills do today (DBE, 2004, 2020; DHET, 2013).

Consequently, today we know of other ways and other places where science practical work can be conducted. Practical work can now be conducted with through digital technologies and even in any other environment like your home kitchen, your bedroom or even outside depending on the approach taken (Aththibby & Kuswanto, 2021; Pols, 2020). As Millar (2008) alluded to that practical work is vast and as such it cannot be viewed one light and cannot be analysed in the same way. This case presented the ways in which physics practical work was approached by both teacher educators and preservice teachers in the remote learning context, revealing the kind of practical work chosen. The section discusses the design as in how the practical work was envisaged and the implementation which is how the designed translated into reality for both teacher educators and preservice teachers.

6.2.1. The design and implementation: The Intended nature of practical work

In essence, the design and implementation came to be due to the context under which teaching and learning had to occur. Teacher educators thought, in the absence of the physical laboratory, scientific apparatus and in the presence and mediation of digital technologies, hands-on practical work is key for training prospect teachers who will teach in South African ordinary schools. The nature of the designed and implemented practical work is discussed with the kind of practical work chosen accompanied by the teaching and learning objectives and the actual facilitation and learning as found in chapter 5 to paint a full picture of the nature of practical work engaged in for the course.

6.2.1.1. Guided Kitchen Table Practical work

The remote learning context meant that teacher educators and preservice teachers were to connect only through digital platforms for teaching and learning processes. In the absence of a physical laboratory with appropriate lab apparatus, one would assume that non-physical engagements and processes would be a default approach where students are not too involved in motor coordination exercises to get tasks done. Aththibby and Kuswanto (2021) argue in their systematic literature review that in the remote learning context, virtual labs, video analysis and remote labs were factored into the teaching of physics practical work and further added that under such a learning context creativity and positive attitudes is rather contradicted.

However, in this case where learning occurred remotely, teacher educators still found a way to have student engage in practical work where they needed to use their hands to get things done. Millar (2009) define practical work as a kind of science teaching and learning activity where students are engaged in physically manipulating and observing materials to construct and build knowledge and understanding of science ideas. He further state that there are different types of practical work, which are open investigations and close-ended or structured investigations. Preservice teachers in this study were engaged in closed-ended practical work, where they were guided into what to do and how to do it through the practical work manuals. And in the absence of science lab and materials, the kitchen and its materials were the chosen working space for this case. The guided Kitchen Table Practical work was unique to this case when with the literature I have engaged with. In some case The Kitchen Table Practical Work approach was used, however students were liberty to guide their investigations that is the practical work activities were rather open ended and, in some cases, digital tools based practical work were chosen for students to engage in (Pols, 2020; Aththibby & Kuswanto, 2021; Beans, 2020).

For the above cases, though subjected to the remote teaching and learning conditions, I believe they were influenced by different other contextual issues. Which for a start the nature of the courses under which the design came to be and the different course instructors each study explored. Shulman (1986) alluded that a teacher in their approach must always integrate their pedagogical and content knowledge taking into consideration students' learning context/environments, what students know already in relation to the teaching and learning objectives. The explored literature reports on events on the main stream science whereas this case explored the science in the humanities where prospect teachers are trained to teach science in the South African schooling context. The course presenters had different teaching and learning objectives and as such designed and implemented the kind of practical work that they thought will allow them achieve their objectives.

6.2.1.2. Teaching and Learning objectives

Integral to teaching and learning are objectives, which communicates what need to be learned, how it is to be learned, why it is to be learned and by whom it is to be learned. In Bloom et. Al (1956) teaching and learning objectives are referred to as educational objectives which are defined as "explicit formulations of the ways in which students are expected to be changed by the educative process" (p. 26). These are either tangible or not and can be or not measured. The objectives encompass skills, attitudes and knowledge all together. Bloom et.al., (1956) and O' Clair (2017) alludes to learning objectives as measurable skills or knowledge that students should attain after going through learning of a specific subject. In the current presented case, even though the learning objectives were not explicitly stated in the manuals, the analysis as presented in chapter 5 found that there were indeed educational or learning objectives attached to the specific practical work chosen. The teaching and learning objectives proved to be subject knowledge specific, and pedagogy knowledge induced, that is bound to creating feasible learning approach for preservice teachers' learning context and environment and their development either in character or attitudes.

Subject knowledge specific objectives

Subject knowledge specific refers to science practical work, particularly physics as a knowledge discipline and practical work as a teaching and learning strategy for physics. For subject specific, the central learning objectives for the chosen practical work was to have students learn scientific knowledge and gain scientific enquiry skills through hands-on practical work where students engage with materials to observe a particular science phenomenon. The design promoted students knowing of scientific concepts and having them physically manipulate materials or objects in their homes. Just as in Millar (2004) this study found that the design of practical work is still much in line with the aims of science education which seems to prevail as also in other studies over the years. Science education aims: "to help students to gain an understanding of as much of the established body of scientific knowledge as is appropriate to their needs, interest, capacities; to develop students' understanding of the methods by which this knowledge has been gained, and our grounds for confidence in it" (Millar, 2004, p. 1). Sani (2014) found that "aims in terms of practical work can be classified into: conceptual, procedural and affective domains" (p. 1016). The lecturer emphasised students having to understand the scientific concepts and having to give students practical skills, where they have to be hands-on with the simple accessible material. Figure 23 below summaries the subject learning objectives of the practical work and other knowledge structures that supported the subject specific learning objectives as found in the practical work manuals.

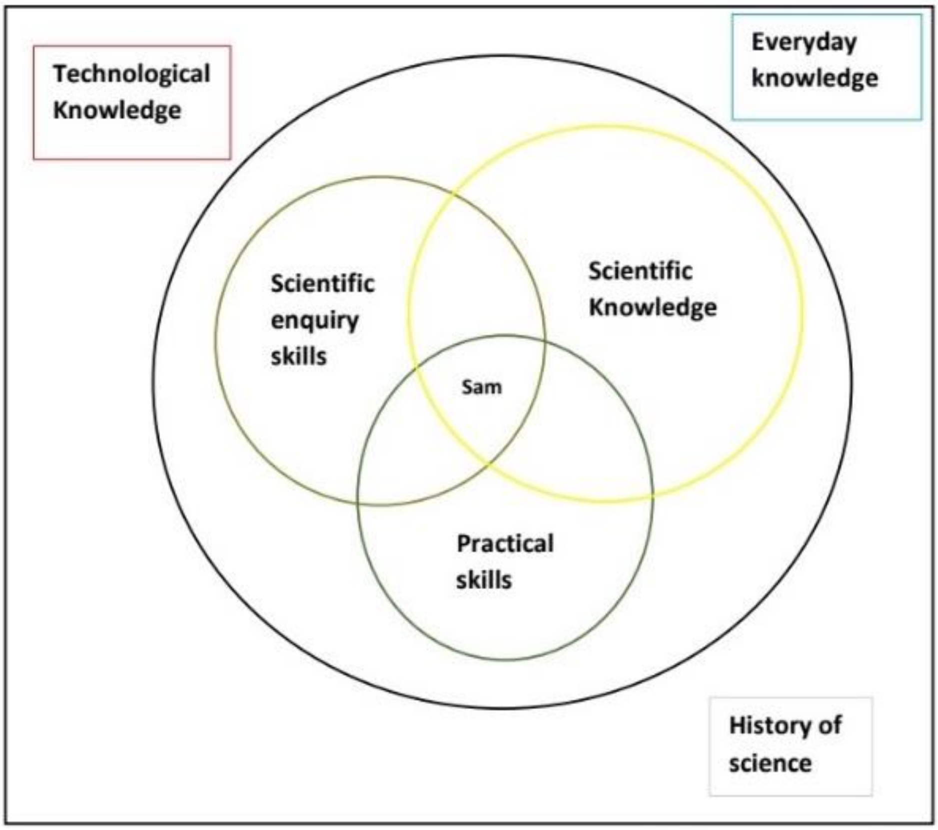


Figure 18: Summary of the practical work learning objectives and other knowledge structures found in the design of practical work.

In figure 23, central to the subject specific objectives are three knowledge/skills sets that are interconnected by central point which describe the Kitchen Table Practical Work approach. The objectives of the Kitchen Table Practical work approach were to have the preservice teacher understand set scientific ideas, use and gain scientific enquiry skills and lastly to engage in or gain practical skills by using simple materials which are mostly kitchen-based materials that are easily accessible from their kitchen or elsewhere beside the laboratory. On the periphery of central subject specific objectives are the extra knowledge bases that supported the main objectives. That is the Technological Knowledge, Every Knowledge and History of

Sciences were not central rather to the objectives of doing the practical work itself, their occurrences in the practical work manual design suggest to be support knowledge structures to either drive or facilitate the main objectives.

Simple accessible material (Sam) in this case meant resources for learning and engaging in practical work. These are various objects or materials (apparatus) different from sophisticated scientific apparatus used in the science laboratory. They meant improvised materials that preservice teachers had to find in their kitchen or purchase at low prices in local supermarkets or spaza. The improvised materials as unique to this study were not tested for accuracy or assurance that they would yield accurate results. Using the improvised materials, preservice teachers, had to construct the scientific knowledge. They had to be hands-on and practically manipulate the prescribed materials in the best way they knowledge how to get to know what they had to know.

The use of simple materials was unique to this case when compared to other similar studies presented in research literature. This case suggest that scientific apparatus was to be replaced with any other ready-made materials aimed for a different purpose can still be used for the purpose of constructing science knowledge. The idea was for preservice teachers to turn their kitchens into a laboratory and use materials found in the kitchen as apparatus, such as utensils, other kitchen products such straws and food staffs (Tin of Beans/fish). This is different from the Do it yourself (DIY) creation approach where the preservice teachers were to use different materials to create, design or decorate (redesign) a resource or resources or apparatus (Gya & Bjune, 2021). The instructions were, use one, two and three or something similar, as it is and do practical work.

Furthermore, other course instructors, under remote learning conditions, sent apparatus to their students in their respective homes for students to engage hands-on with science practical work (Michael et. Al., 2021). In another study, students were engaged in using kitchen processes such as cooking or baking where students had to in their respective kitchens cook or basic following recipes to learn about specific science ideas (Beans, 2020). I would classify such an approach as an analogical demonstration or practical work, so even though the kitchen is the ultimate space for conducting practical work for this case and the case of Beans (2020), the design is different still. In another Pols (2020) students had to use whatever is available at home to design their own enquiries, that is specific develop their own steps or procedure, choose their own materials in their homes, measure and record the results. The approach to practical work in Pols (202) is rather different to the study in this case as students were engaged in open investigation or enquiry where students solely guided themselves through the task, which is contrary to guided approach to practical work where preservice teachers were given the manuals with suggested or prescribed materials for the work. One would argue that student's autonomy was limited in this case as compared to the three studies above.

Interestingly, Pols (2020), Beans (2020), Michael et. Al. (2021) and this case emphasise that central to the practical work approach is the scientific ideas or knowledge and scientific enquiry skills even though they are each of different science discipline. Pols (2020) report that "students had to develop a variety of physics concepts such as the wavelength of sodium or mercury, the Boltzmann constant using the (V, I)-characteristic of a diode, or the dissolution enthalpy of salt (p. 172). In Beans (2020) "students had to engage in baking of chocolate cake to learn chemistry concepts such as Heat diffusion, the movement of thermal energy through a material" (p. 20983). The preservice teachers had to construct the scientific knowledge as already established by other scientist and they also had to use and enhance their scientific enquiry skills and, in the process, construct their own way of knowing science knowledge. They had to observe, measure, record and make conclusions about specific physics knowledge. Central science ideas in the three manuals were Simple Harmonic motion, waves using the wave model, Hooke's law, Measurements and Simple pendulum. See figure 24 below, Millar (2004) presented the core aims or objectives of science practical work.

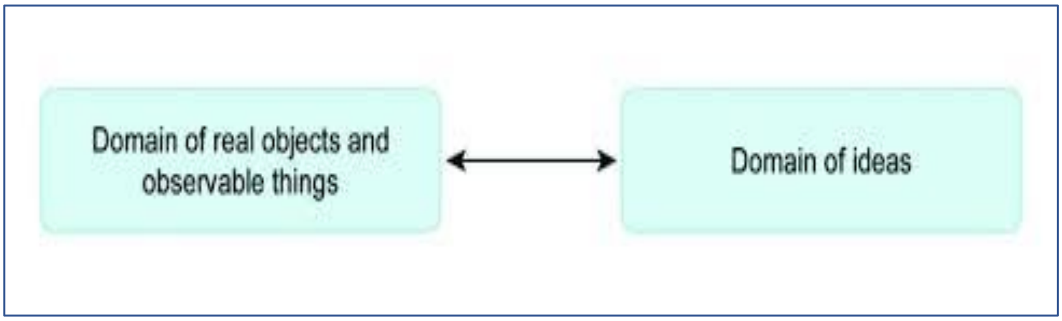


Figure 19:Practical work: linking two domains of knowledge (adopted from Millar 2004)

The core learning objective as found to be scientific knowledge, practical skill and scientific enquiry skills interlinked by simple materials can be summarised with Millar (2004) where the scientific knowledge (the idea domain) are generated through scientific enquiry skills and practical skills of handling materials (Domain of real objects and observable things).

Pedagogical Knowledge induced objectives

Pedagogical knowledge induced or teaching objectives in this study refers to the not so measurable gains that teachers want students to attain from engaging with the knowledge or various activities. These are knowledge, skills and attitudes that are not subject specific and not normally explicitly mentioned as they are not evaluated or assessed. However, the teacher sees or deem fit for the students to develop in such skills, knowledge and attitudes. Bloom et. al., (1956) stated that "the formulation of educational objectives is a matter of conscious choice on the part of the teaching staff, based on previous experience and aided by consideration of several kinds of data" (p. 26). Teaching objectives are induced by teacher's knowledge of students and the aims of why they are taught, which can be summarised as knowledge of the curriculum and its objectives, prior knowledge, learning context and environment. In this case, it was the teacher educators' knowledge of the preservice teachers' learning environment and remote context, the context under which they will qualify to impact and preservice teachers' prior knowledge. In this context the teacher educators had a background information of the kind of practical work preservice teachers previously engaged with and prior knowledge about the subject content preservice had to know through the practical work.

Implicitly, teacher educators promoted three other knowledge structures that emerged from the analysis of the practical work manual. These three knowledge structures are located outside the circle in figure 23 as they are not as widely used across the three practical work manuals. Preservice educators had to have or develop technological knowledge which were meant to be used mostly for administrative purposes, on the other hand the Everyday knowledge and History of science were some sort of strategies embedded in instructions or theory presented in the manual. The three knowledge structures were not core to the chosen practical work.

The three knowledge sets bring in the idea of teacher knowledge of teaching physics practical work to the set group of students under the given remote teaching and learning conditions. These three knowledge structures also bring out to the front the contextual factors into teaching physics practical work. The everyday knowledge is used to relate science concepts and knowledge to preservice teachers' experience so to help them grasp the concepts they had to study. Stears et al., (2003) states that use of everyday knowledge to relate and build students' experiences, interests and prior knowledge in learning science is much encouraged in the teaching of science. The History of science in this study was not as strong as it made just one appearance in practical 2 manual, which was just a mention in passing to state the origin of the application of pendulums in clocks, as the focus on the manual was on simple pendulum.

Technological knowledge (TK) in this case was intended for administrative purposes as it was embedded mostly in instructions. Technological knowledge refers to the knowledge and use of digital technologies for submission of practical work report which was really embedded in the instructions. TK feature instructions on what digital technologies they had to use to organise their knowledge as they learned through the practical work they engaged in for assessments. TK arise in each manual, due to the conditions of learning where teaching and learning processes are facilitated through the digital platforms. Digital technologies were central to learning even though preservice teachers had to physically engage on practical work. They had to do have online engagements with their teachers and/or even their peers. They typed their report on MS Word submitted through for feedback through the University Learning Management System (ULMS). Preservice teachers engaged with their lab demonstrators during scheduled lab sessions via WhatsApp. Technology integration as intended by the design team was to promote access to human assistance and interactions than issues of use for science knowledge and understanding. Kouser and Majid (2021) alluded to the fact that technology has changed drastically over the years where it is not only just bound to the classroom, but the internet at high speed now connects devices across the world. As such the use of technology has gone beyond the classroom in education. It was explicit in this study and other studies that technology was central in connective classmates, students and teachers from the comfort of their homes and have learning continue meaninglessly.

Furthermore, the interviews with teacher educators gave insights of the teaching approach altogether giving a broader perspective into how learning was to be achieved beyond the subject specific learning objectives as per the practical work. The design team state the thinking and reasoning behind the chosen practical work which reveals general perception about teaching practical work and overall teaching objectives to the particular group of students in this 3rd year teacher education physic course. Figure 25 below summarise the overall aims of teaching physics practical work to the student teachers.

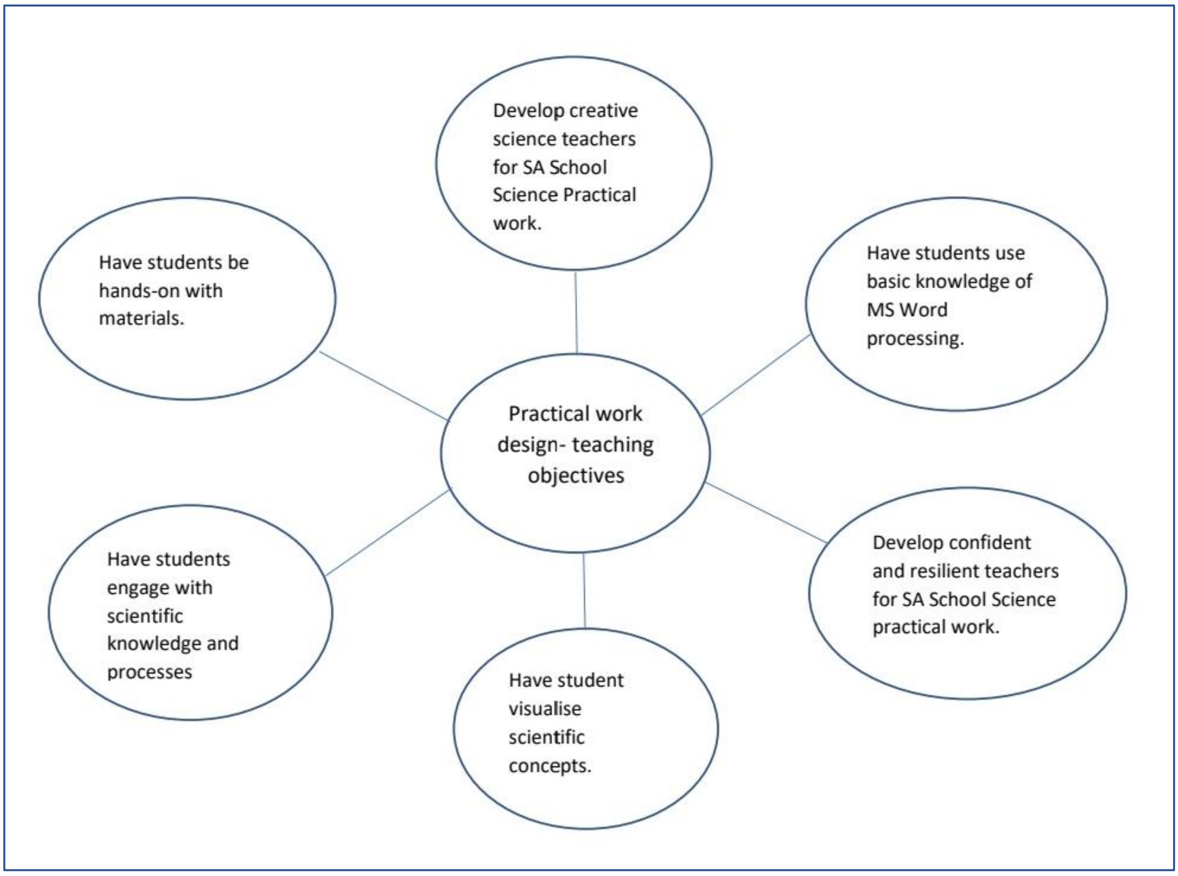


Figure 20: Summary of physics practical work teaching objectives for prospect teachers

Teacher educators in their approach intended to have students actively involved in the practical work, where they had to drive their own learning with the task sheet guide given together with the available human assistance. Self-directed learning was central to the remote conditions where preservice teachers worked through the task at their own pace, most especially as they were connected with their teachers via digital platforms. Kouser and Majid (2021) state that the presence and use of digital tools promote self-directed learning where students can learn at their own pace as well. This kind of students centred approach to learning is consistent with the views that students learn better when they conduct practical work by themselves and construct their own knowledge as alluded to in Millar (2009). It was in preservice teachers connecting the prescribed improvised materials that the learning objectives as intended by the design team would be achieved. Preservice teacher engaging and visualising science concepts practically was vital as discovered in the practical manuals. Additionally, from the entire practice they had to come out resilient and confident to teach and implement practical work in the ordinary south African high school in any case.

South African schools are largely traditional with limited to no scientific apparatus or laboratories as reported by the expert consultant in the interview. Several studies report lack of resources as central factor affecting the non-enactment of practical work in teaching science (Tsakeni, 2018; Ramnarain & Hlatshwayo, 2018). Aside from the lack thereof apparatus or laboratory South African teachers are reported to not engage learners in science practical work. They are found to teach science from textbooks, they misinterpret practical work, lack innovation to engage learners in practical work, they lack appropriate model for practical work, not confident or rather they are just not interested in practical work (Mogofe & Kibirige, 2013; Oguoma, 2018; Tsakeni, 2018; Gudyanga & Jita, 2019). The design team found an opportunity to respond to the challenges of south African schools in implementing practical by first engaging prospect teachers physically and practically in practical work even under the remote learning conditions. With this step, they were aiming to develop resilient, confident and creative teachers who are going to be innovative with various challenges they will come across in their physics teaching journey to ensure that their learners engage with practical work in South African Science classrooms.

6.2.2. The implementation: The Enacted nature of practical work.

Students' learning of the guided kitchen table practical work was approached with various strategies and materials even though they were prescribed for use of listed simple materials to foster the hands-on and doing science. Just as the practical work design had the simple materials suggested, two of the preservice teachers out of the three had to improvise further as the suggested materials was not easily accessible as assumed to be by the design team. In actual fact, the assumed simple materials were not as simple from the preservice teacher teachers' perspective. The prescribed simple materials were not simply accessible, due to mainly affordability issues and even geographical location.

The two preservice teachers were left with no choice but to think along the lines of what was prescribed, they had to find something similar to what was prescribed. The elastic rubber band as prescribe in practical work 1 manual translated to an elastic mask string from the COVID-19 spread prevention face musk for one prospect teacher and an unspecified texture of a string of at least 1m long length translated to a rather too thin string to hold pendulum for another student in practical work 2 manual. These realities were not intended by the teacher educators, but context materialised them into actuality of the practical work. Pols (2020) suggest that students in his course had to design their own enquiries and even choose their materials, and the preservice teachers in this had to make judgements and improvise on materials further than what the teacher educators had envisaged.

The preservice teachers in their quest to develop the scientific knowledge and scientific enquiry skills proved quite proactive and creative in thinking about the materials they would rather use as they did not have the prescribed materials. So, as requested to find whatever similar in their kitchens or rooms students were proactive enough to find and try a similar thing to what was prescribed. The preservice teachers in this case took ownership of their learning as inquiry-based learning requires students to take charge by driving learning as they deem fit for their context (Millar, 2010; Caswell & LaBrie, 2017; Gholam, 2019). Finding a similar thing proved problematic for accuracy which left student doubtful and not confident with the knowledge they were constructing in the very much self-directed learning (Yildiz-Feyzioglu and Demirci, 2021). There were uncertainties with observations as stated by ST03 in practical 2 due to the limited abilities of the used string to hold and allow the pendulum swing as stated in the lecture notes given to them during the course work.

The preservice teachers proved doubtful and lacking confidence in working with the improvised and even the prescribed materials as they resorted to use of digital tools to complement the prescribed hands-on practical work. Preservice teachers' use of YouTube videos and sometimes google search was for them a safe approach to confirm their actions when engaging with the intended practical work. While the use of digital tools does not clarify the impact on level of openness of the inquiry-based task to learning and mastering scientific concept or enquiry processes, however it reveals to an extend the preservice teacher's lack of confidence in knowledge construction in the self-directed learning (Yildiz-Feyzioglu and Demirci, 2021).

The students found seeing the concepts through the improvised materials very interesting even though they were doubtful of the knowledge constructed from it. It was the knowledge constructed from the hands-on practical work that were reflected upon with the teacher educators as they asked clarity questions. Students being in doubt and lacking confidence in constructing science knowledge has proven a trend in science related subjects. Colwell et al., (2002) states that "knowledge construction for science learners has proven difficult particularly because they have to develop both conceptual and procedural knowledge" (p. 74). This study found that students were not so confident in the material they were using, how they put the materials together and in how they went about manipulating the materials to make their observations and measurements even though they were given guiding instructions on a recipe-type worksheet. The preservice teachers' knowledge construction was indeed in a doubtful state though they found the intended practical work approach interesting. students may find engaging science as prescribe interesting, but doubtful in their approach because it is their first time engaging or doing science with simple materials as compared to designated materials they used in the laboratory. Moreover, also because the practical activities were guided by the teacher educators in that the concepts and procedures of inquiry were conceptualised for them and they had to take full ownership of their learning as they geographically apart from their teachers. Nzomo et al., (2023) states that "the inquiry-based approaches begin with practically no students' flexibility but end with the students having total control in the learning process" (p.2). Preservice teachers in their quest for knowledge and in the process of knowledge construction ended up doubling the efforts by using digital tools to mediate learning. students stated that they knew that someone did something similar somewhere so that allowed them to see first from the YouTube videos before they could connect the materials themselves.

6.3. Factors influencing the teaching and learning of practical work in the remote learning context.

At the heart of teaching and learning are always resourceful tools either in human form or facilities that affect how the processes unfold. These resources become key variables to the processes in a way that without them processes would not/ not successfully be in place. One would at some point want to test and confirm these variables as to how much of influence do they have on the teaching and learning process. Influencing factors can in one way or the other and in different degrees affect the outlook of the target object. Influencing factors can be relatively good or bad, depending on matter or space or time or observer, or all in part or in whole. Key influential factors presented in chapter 5 and discussed in this section are the use and availability of digital tools, availability or not of materials and the inevitable student centeredness learning approach. These factors influenced the teaching and learning of practical work in one way or the other.

6.3.1. Teaching and Learning resources

One can imagine that resources are central to teaching and learning hence they form a big part of the lesson planning and delivery (Shulman, 1986; Bušljeta, 2013). Bušljeta (2013) stated that "in the context of classes as an institutionalised form of teaching and learning, teaching and learning resources could be defined as the instruments of presentation and transmission of the prescribed educational material" (p. 56). The key resources in this current study refers to digital technologies and the simple accessible materials as found in chapter 5. The digital technologies found more expression in the remote learning context than ever before, where their absence meant no or little access to education. This was very much visible in the hardcore lockdown when tertiary institutions moved online to continue learning while majority of schools in basic education institution went on a complete closure of their doors (Mhlanga & Moloi, 2020).

Digital technologies were key for administrative, instructional and learning purposes. Digital platforms were used as the meeting place connecting both teacher educators and preservice teacher, they ensured that practical work manuals are accessible to preservice teachers and that teacher educators access the submitted scripts. Just as alluded to in Kouser and Majid (2021) the internet played such a crucial role in ensuring that administration and learning occurs for the teaching and learning processes altogether in this case. Teacher educators and preservice teachers reflected that as in when network is interrupted they would miss sessions altogether. Kouser and Majid (2021) stated that "the internet helps connect those devices and can connect students in the classrooms, through schools or around the world" (p. 366). It was through the internet that the digital devices and the applications were able to be useful for teaching and learning processes. Preservice teachers and Lab demonstrators went over board and used some of the digital applications to enhance learning. They used apps such as YouTube to enhance their own understanding of the scientific content, to understand the given instruction and to also see in actuality how the instructions they had to follow from the manual guide might have looked like for other people who have done it before. One would assume that without the internet, digital devices and the digital tools learning under remote learning context would not come fruition.

Moreover, for this particular case the prescribed simple materials played a key in learning practical work. The choice of the materials for conducting practical work was not envisaged to be complex hence the teacher educators refer to them as simple accessible materials, however experience taught us that perhaps they may be simple materials but not so much accessible with respect to the prospect teachers. The prescribed materials were the chosen learning materials to help the preservice teachers to construct the specific scientific knowledge and ideas, as such played a crucial role for the hands-on practical work. Preservice teachers had to in one way or the other find the materials even went on to further improvise when they could not find the already prescribed simple materials. Even though they had a chance and choice to also look up some YouTube videos for reference they still had to get hands-on with the materials and follow the practical work manuals guideline to engage with the prescribed practical work. Two of the preservice teachers went on to simplify the material further with similar materials. That put the practical work materials central to having the preservice teachers gain the intended understanding of science concepts, scientific enquiry skills and the practical skills.

Although, the current study was not testing for the effect of using the prescribed apparatus on achievements, one can assume that the availability and use of these materials can impact on achievements and various aspects of learning. Olufunke (2012) suggest that the availability and utilisation of materials used for learning are factors that may affect student's achievement. It is reflected by ST02 and ST03 that they actually did not trust the materials they had to find in place of the prescribed materials. This may translate to lack of confidence in the materials. One of the most popular factors to lack of incorporating practical work into the teaching and learning of science in South Africa is the lack of materials and also teachers' confidence in their ability and skills to actually carry out and direct the practical work (Mogofe & Kibirige, 2013; Tsakeni, 2018). The course in having the preservice teachers work with home-based materials for learning is rather confronting both the issues of confidence and of materials, because the prospect teachers managed to look for materials and with the less confidence they still went on to connect the materials they found and made observations.

6.3.2. Learning approach: Student Centeredness

The remote teaching and learning context enforced the student driven practical work where teacher educators had minimal impact or effect on how students conduct the practical work. As teaching and learning occurred through digital platforms teachers could not oversee students' learning process. Just like in Michael et al., (2021) teachers had to rely on practical work schedule hoping that students are really engaging in practical work as prescribed and guided by the practical work manuals in the given period. While students in Michael et a., (2021) students had to do open-ended investigations where they formulate their own research projects, students in this case were rather guided through practical work with task manual sheets on what they needed to do to learn or grasp the science concept just as stated in Millar (2010). Teacher educators influenced the learning of practical work design through conceptualised design which meant they had control over what students had to learn and what they needed to do in the given tasks, which ultimately effected assessment to be uniform for all students.

However, it is quite important to reflect on the fact that the practical work design was highly based on improvisation, where the materials used were not as accurate for physics practical work as in the normal science laboratory. And though the prescribe materials were already improvised. Preservice teachers were also encouraged to improvise further with materials in case they do not get the already prescribed improvised materials. So, to a greater extent the preservice teachers were at liberty to direct their own learning and at their own pace. This form of practical work and remote learning conditions where learning was driven through digital technologies ensured that the student-centred learning is supported as alluded that hands-on practical or rather inquiry-based learning support student centred approach to learning (Snetinova, Kacovsky & Machalicka, 2018). Also, just alluded to in Kouser and Majid (2021) that "While incorporating technology in teaching makes lessons fun and joyful for the students, the students can learn at their own pace that is at anywhere and at any time they can easily access the desired content with the help of technology and can learn easily" (p. 367).

Even though students had to take ownership of learning, teacher educators beyond just conceptualising the tasks sheet, made themselves available to assist students for the given time period as per the schedule. The briefing/debriefing during lecture session and the discussion during the practical work sessions were put in place to have students share ideas and reflect on their experiences as mentioned by the instructor and the lab demis. Score (2008) states that "it is of great importance for teachers to help students to make an understanding of their findings by comparing with their peers and with a wider science community" (p. 7). Teacher intervention though not so effective through digital platforms as mentioned by both teacher educators and preservice teachers in this case is of great importance in students understanding all the intended learning objectives (Abraham & Millar, 2008). Therefore, teacher educators needed to outline all learning and teaching objectives clearly on the practical work manual in a case where they are not fully and physical present with students to guide their understanding of the tasks. This is one fact that teacher educators altogether overlooked even though they had the intervention strategies of using WhatsApp platforms and being available at set slot to assist the preservice teachers. The teacher educators' focus was rather on preservice teachers actually engaging the work as guided in the practical work manual and having them experience everything that came with doing the tasks as prescribed. Thus, they required the preservice teachers to provide evidence of their setup of practical work and sharing their experiences by asking clarity question for discussion during the scheduled times.

6.4. Teacher educators and Preservice teachers' experiences of practical work in the remote learning context.

As mention in the previous section influencing factors can be good or bad, some people would say they can be positively or negatively impactful. How factors effected changed can be narrated through how they were experienced in relation to the targeted objects. In context of this study, that is how the learning and teaching resources as in, digital technologies & Simple Materials and the, learning approach as Materials one of the key factors were experienced in the teaching and learning of practical work. This section discusses teacher educators and preservice teachers' experiences of teaching and learning practical work, which the experiences are revealed as opportunities and limitations (challenges) reported in subsection 6.4.1 and 6.4.2 respectively.

6.4.1. Opportunities for teaching and learning Practical work

One would say change is not always bad, sometimes change is good, but the impact or effect of change is always subjective to the offender. The participants in this study, the preservice teachers in particular were faced with some opportunities which were induced by the remote learning conditions. Teacher educators on the other hand were somehow more limited as compared to the preservice teachers. The students centred learning approach rather empowered the preservice teachers, where they were more autonomous in making decisions concerning the materials and other resources they wanted to use. Moreover, the preservice teachers experienced to an extent, some liberty to choose their learning conditions and who to work with in the process. This subsection discusses, preservice teachers' freedom to direct their own learning and approach and view it as preservice teachers' autonomy and agency in the learning of physics practical work.

6.4.1.1. Preservice teachers' autonomy and agency

Student teachers proved to be autonomous in their approach to learning practical work. They were at liberty to use of digital tools to enable science knowledge construction. They used the simulations and YouTube videos to support the given practical work manual guide, and visualise the concept and guide their way of following the procedure. While teachers educators in the manuals design intended for students to make use of the available assistance in the form of prescribed textbooks and Lab demis, students rather added to it the use of digital technologies to aid their learning of practical work. Figure 26 below present the intended and enacted learning resources for practical work by students. That is the envisage (intended) approach to learning practical work as per the practical work manual and the actual (enacted) approach to learning practical work.

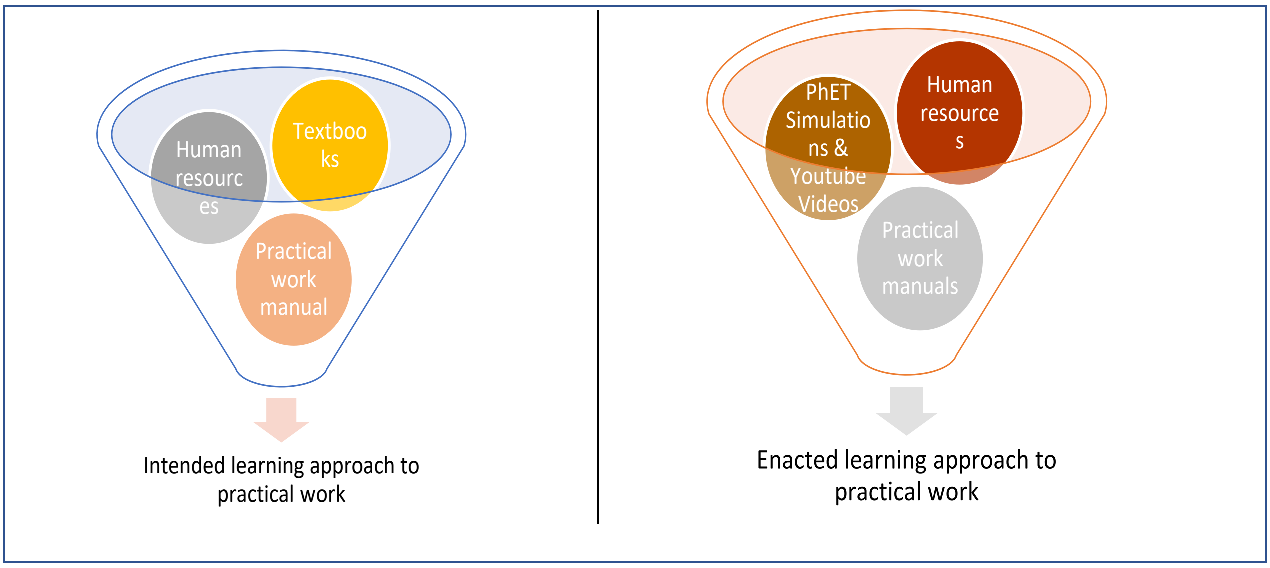


Figure 21: The intended vs the enacted learning resources to aid the learning of practical work.

In the current world where information is digitised, students went beyond using digital technologies for communication and engagement with their Lab demis, to incorporating digital tools as aids to learning the science content they were intended to learn though hands-on approach. While the teacher educators were available to assist students with queries, the preservice teachers saw it fit to also mediate their learning with various digital tools. They used this approach due to the time period scheduled for engagements with their teachers to help clarify some of their learning steps. The preservice teachers mentioned that beyond the scheduled practical work session period, the Lab demis would not respond to the questions they would ask in the WhatsApp group dedicated for learning practical work.

The preservice teachers were able to apply their autonomy in selecting resources at their disposal to mediate learning of both science concepts and enquiry processes. They chose convenience as they did not overall disregard teacher educators' assistance to learning practical work, they complemented and supplemented the available human resources with available digital resources to aid their learning. The students used this approach for knowing and understanding the science beyond task textbook and the practical work manuals says. It is important to also highlight that teacher educators or rather the design team in this case anticipated their students to approach learning of the practical through following the scaffolded practical work manual, textbook explanation and make use Lab demis in the dedicated time to clarify some of their concerns or struggles. This rather appeared not enough and they took it upon themselves to inquire with other resources for clarity.

Scaffolding is quite important in inquiry-based learning. This study found that scaffolding need to be viewed beyond the teachers' intervention to assist and guide students as their involvement is much more limited due to the teaching and learning context. Remote learning meant that scaffolding as it occurs within reach of the teacher educators, their efforts needed to be extended with use of readily available digital resources to assist and guide learning where teachers could not. Students stated that there was no demonstration from the Lab demis as such the simulations and YouTube videos helped to demonstrate how they needed to do it on their own. The simulations according to ST03 also confirmed the textbook explanation of the science concepts under study, as compared to the connected improvised materials. The preservice teachers also added that with the availed human assistance, some of their misconceptions would go uncorrected due to the schedules and nature of remote learning. They therefore appear to trust the knowledge construction through the aid digital tools such as simulations and YouTube videos. Preservice teachers in their doubt and dissatisfaction with experiences with the prescribed materials were bold enough to think beyond what it is made available to them for learning. They all exercised their autonomy and took charge of their learning in the designed practical work (Millar, 2008; Yildiz-Feyzioglu & Demirci, 2021).

While students were so autonomous in their learning approach, by choosing to supplement the given practical work with use of digital tools, they continued to conduct the practical work as prescribed. And went through the experiences of the unsophisticated materials as prescribed for them. With their learning approach they have had a rich experience which impact so much on their becoming a science teacher for South African Schools. They mentioned that there are certain practical tasks that you cannot not do with learner and definitely there are practical task that requires you to have students be hands-on. They arrived at a conclusion that digital practical work cannot replace physical laboratory work where students are hands-on with the materials regardless. Though proves difficult for teachers to engage students in hands-on practical work due to lack of materials, the preservice teachers believe so much in creativity and innovation to make practical work a reality in schools. They reported that through the chosen kitchen table practical work, to have experience a shift in thoughts towards creativity and innovation to drive the incorporation of practical work as prescribe in the curriculum for learning science regardless of the lack of resources (DBE, 2012; Rollnick, 2021).

Additionally, the remote learning conditions had preservice teachers geographical apart from their teacher educators where communication and engagement between them occurred through digital platforms. The prospect teachers were generally found to prefer working individually.

Even though the nature of science is known to promote collaborative learning, they did not find collaboration with fellow students a good strategy for learning in the remote learning conditions due to fears of academic misconduct, chaos and exploitation. Moreover, collaboration was also found to be chaotic as large group of students unsupervised could not arrive to a decision together, that is, on what to do and how to go about it even though they had the practical work manual guiding them in practical 3 that they had to do together due to limited resources. This feeds directly into the limited teacher involvement in directing students' actions in conducting the practical work. Grant (2002) suggest "that project-based learning such as problem-solving investigations and other experiential learning, as in this case allows students individual or teamwork without teachers' extensive involvement in the work they do" (p. 36). However, the teacher educators as the knowledgeable other in terms of teaching and learning objectives would have created a conducive environment for collaborative learning and chaos would not be a factor to hindering collaborative learning. I would assume teacher educators in this case did not think beyond the teaching and learning objectives discussed in chapter 6.2 just as there was no particular teaching strategy other than discussions. With the unstructured teaching approach to delivering practical work session impacted greatly on learning strategies. The preservice teachers were on learning strategy, Trial and Error mode to enable their understanding of science knowledge and processes with the practical work they engaged on. Of which they regarded the Trial-and-Error approach beneficial or rather an opportunity to explore various ways to get to know through use of digital tools, the manual guide and any other resources that could help them.

Although collaboration learning was close to impossible in this case, it is rather one important aspect in science teaching and learning or rather in science in general. Millar (2004) states that "science in its nature is said to be a social institution where members of the community engage in the knowledge construction through making links between data and explanations" (p. 1). In this case the peer-peer and students to teachers' interactions were rather limited due to the remote learning conditions. However, it is important to emphasise that they were not prohibited, students were also encouraged to collaborate with each other as seen in practical manual 1 and 3. The learning approach taken as discussed above imply that students thinking and reasoning in the construction of science knowledge was limited to their interactions with the digital tools and the science community on those tools. The immediate science community did not have space and opportunity for critical engagement towards building science knowledge this learning context and environment. Yildiz-Feyzioglu and Demirci (2021) emphasise (as in Millar, 2004) the point that science knowledge is created through engagements of critics and confirmation through debates with fellow science community members.

Important to note is the confidence students had in information found on digital tools to confirm the knowledge they were creating. Which imply that is essence the preservice teachers aimed mainly at confirming what is already known in science, and the light of knowledge creation and understanding the tasks as per the design of the practical work manual was in its entirety limited. The aspect of critics and critical engagements on the observations made and data collected is not evident in the approach students took to learning practical work. As one lab demonstrator mention in the interview "students would be excited when they get answers right during the lab sessions". Though this could have been triangulated with observations, but preservice teachers' action of confirming knowledge and their understanding of the manual guides with use of simulations and YouTube videos warrant the finding that students were more consent with confirming knowledge over creating knowledge. Although the preservice teachers were at liberty to choose how to work on the practical work, and they view that as an opportunity, the limited collaboration with peers hindered critical robust engagements towards science knowledge construction.

6.4.2. Challenges to teaching and learning practical work

In this case study, there were more limitations experienced by the participants than opportunities. This subsection discusses the main challenges as experienced by both teacher educators and the preservice teacher during the teaching and learning of the physics practical work.

6.4.2.1. Poor internet connection, technical glitches and geographical location

The study found that Network connectivity is a contributing factor to teaching and learning in this remote learning tailored practical work. And network connectivity on the other hand is influenced by the electricity supply and the geographical location within the country. Teacher educators report the issue of load shedding which highly affected the stability of their internet connection. Two of the preservice teachers do not report bad connectivity as they resided in university residences, while the other student who stayed far from campus report load shedding and sometimes abrupt power cuts without communication from the municipality. However, the students do not report any casualties where electricity cuts or network work issues impacted them directly in their learning. Even though students do not report bad internet connection directly affecting them, teacher educators having bad network connection impacted on students' learning experience. ST03 mentioned that just as the teacher educator would disconnect and connect to the lesson due to their connectivity issues the energy and enthusiasm to participate decrease because of the instability. Tutors on the other hand mention having to miss or even be late to the session and negotiate with the lab partner to lead the session due to load shedding affecting their area. One tutor mentions having to move between provinces for a better network coverage, while the lecturer had to move from his home to campus to mitigate possible connectivity interruptions due to load shedding.

Remote teaching-learning across the world and in South Africa meant distance and online teaching-learning and this equated to use of digital tools and devices for the communication, engagements and access to information (Mhlanga &Moloi, 2020; Ghory & Ghafory, 2021). This then means the connectedness of devices and tools through network connection, which in this case the connection looked like a internet spectrum disorder. Where if someone is not experiencing bad internet connect in one place, the other person is experiencing it in another place, and this may be the picture of electricity and internet connection in South Africa as whole. Remote teaching-learning and connectivity issues are a reality as they further emphasise the limited control over learning in highly student driven learning conditions such as distance learning and inquiry-based learning. Beyond that the findings also indicate that digital divides are sustained in the country (Naidoo, 2022). Even though it is not fashionable to generalise to the entire country due to the sample of the study, this is evident enough to add to assertion made on the remote learning further highlighting the inequalities amongst students and perhaps the findings of this study also bringing to light teachers as well (Naidoo, 2022). It is however, not evident enough to generalise this to other similar population in other institutions of higher learning as learning may have been experienced differently due whatever additional circumstances or approaches other institutions went through.

6.4.2.2. Preservice teachers' willingness to participate

Under the circumstance students' attitudes and behaviour were also some of the identified factors to impact the teaching and learning experiences (Hollister, Nair & Chukoskie, 2022). This study found that students will participate during the session influenced how teacher educators facilitate the learning process. teacher educators report that their actions were limited by students' engagement during the scheduled sessions and that were operate on hope that students were really doing the work as they were not actively participating. The study also reveals some factors influencing the students' will to participating, and those factors includes technical glitches, the constant disturbance due to network failure, the scheduled practical work time which limited students to asking questions within a specific time and beyond that time they would not get assisted and lastly students claim ineffective support and guide from the lab demis. All these factors are reported to have students lose interest in participating or engaging during the session because they believe that they would not get help as they require it. The students' problem with maintaining interest has also been reported by other researchers (Means and Neisler, 2021; Hollister, Nair & Chukoskie, 2022). However, students in this case were quite fascinated with having to do the practical work by themselves in their homes, as they say that practical work was not fully online, so they had to do the practical work by themselves and that was interesting.

Though students' will to engage was not core factor to actually conducting the practical work, it impacted the facilitation greatly as the teacher educators were most of the times in the dark in terms of students work. Teacher educators report uncertainties with students' progress or challenges as they are busy with the work and that students tend to communicate their challenges late which at times meant they do not get assisted as time would have lapsed for intervention. Students' will to engage in this case can be associated with the affective engagement dimension. Hollister, Nair & Chukoskie (2022) define affective engagement as "the emotional investment in learning activities and is indicated by positive reactions to the learning environment, peers, and teachers as well as sense of belonging" (p. 2). It is important however to highlight that Students' engagement is a complex matter in teaching and learning, therefore one cannot just make conclusions. and due to its complexity and importance in education it has gained more traction now for research especially now since the teaching and learning environments are constantly evolving due to the rapid rise of digitisation though it dates back to the involvement theory of Austin,1999 (Bond and Bedenlier, 2019). From the students' interview it can be established that losing interest due to technical glitches and connectivity issues as well as limited collaboration and working alone in their homes influenced how and when students choose to engage. These findings on factors influencing students' engagement can further be narrowed or rather broadened to sociocultural influences which are mentioned in Kahu (2013), though not explicitly in this case. The two students who are better positioned in terms of location and access to various other resources such as good internet connectivity and good laptop had a much better experience and got to engage with teachers and the lecturer as they were able to reflect on the effectiveness of tutor support as compared to the one student who did not have a proper working device and did not mention the effectiveness of tutor support rather commented on tutors/lecturer availability to assist where possible. Referencing to their overall performance in the three practical tasks they had to engage with, the two students with a better experience are way above a distinction measure as compared to the other student who is way below average pass mark. That, however, is not evidence enough to link students' engagement to students' performance in this case, hence performance is not an indicator of focus in this study.

6.4.2.3. Lack of materials

Offering practical work in remote learning context has been reported to be a challenge. The remote learning context can be related to distance learning as teacher and students are not in the same environment when learning occurs. Prior the pandemic, the distance learning scholars also alluded to the point that offering practical work is challenging in science related courses such as engineering at tertiary level (Walkington, Pemberton & Eastwell 1994; Estriegana, Medina-Merodio, & Barchino, 2019). Most recent studies on science practical work reflect lecturers deploying various ways of doing practical work in physics or other science related courses. We see the popularity of the use of virtual labs in the remote learning era, video analysis and remote labs (Aththibby & Kuswanto, 2021; Klein et al, 2020). Virtual labs or rather digital labs date to prior the remote learning era (Snetinova, Kacovsky & Machalicka, 2018). Aside from the digital tools based practical work, we see lecturers or teachers coming up with various ways to keep students hands-on with practical work through manipulation of various objects. Teachers either made it a point to get scientific apparatus to students and students conduct the practical work in their kitchens or rather they have students be creative with non-scientific apparatus in their kitchen (Polz, 2020; Michael et al, 2021). In Micheal et. al. (2021) equipment were delivered to students' homes so that they can conduct their practical work and in Pols (2020), it is stated that students had to be creative with materials as they designed their own investigations.

The kitchen table practical work approach is what was chosen in this case and materials were rather crucial to the design, delivery and the learning al together. Well for an African country such as South African just as predicted or found by Rollnick (2021) it is found that the lack of materials is one of the key factors that affected teaching and learning approaches to practical work. It is important to emphasise that the teaching and learning approaches were affected as both teachers' and students were highly influenced by the lack of materials. Aside from the fact the teacher educators improvised with the materials to still get students hands-on under the circumstances, ST02 and ST03 improvised further to get themselves engaged with practical work. Students used different materials to those prescribed by the teacher educators, one used a different elastic band and other students found a string that was different from the prescribed string which the student state that the string was not strong enough to allow proper observation of the concept. Further improvisation meant that standardisation of material was not a factor teacher educator took into consideration for students' learning of practical work. With students in different part of the world, it may have been a factor that students preferred to confirm their knowledge construction by consulting with digital labs than get into conversation and discussion with their peers or tutors. Students stated that the online tailored practical work sessions limited critical engagements that would happen in the laboratory with fellow mates.

Due to the improvisation and lack thereof, students proved to be less confident in the material and their effect on the knowledge construction processes they undertook. We see that in turn also impacted very much on their confidence in the knowledge they were creating as such they chose to be safe and opted to confirm with the "something similar on the internet" than have critical engagements with the peers or tutors in the WhatsApp groups created for teaching and learning. Now the lack of materials primarily impacted more on students as the learning of practical work was more self-directed than teacher-directed.

However, the teaching of practical work was also impacted, because beyond it being an issue of the teaching platform hindering demonstrations, tutors did not do the practical work to be in a better position to guide students. As they said that they relied much on the lecturer giving students all the required information during the briefing sessions. The tutors also relied much on google search to enhance their science knowledge and understanding. Tutors' inability to demonstrate or even do the practical work themselves in their homes hindered effective support or guidance to students, as students complained that even though tutors were available to assist, their support was rather not effective for their learning. Availability of materials in this case proved to be the core factor to teaching and learning practical work, even the design team had to go through trial-and-error process to gauge the relevant materials for the kind of knowledge construction they wanted students to establish

6.5. Chapter summary: A possibility of different approaches to physics practical work.

The rethinking agenda in practical work date back to the early 19th century or prior, even today it is still on the mandate. And that is due to the ongoing questions asked about the role of practical work, who must do practical work and its effectiveness in science education and of course the ever-changing education landscape locally, regionally and globally (Hudson, 1993, Millar, 2004; Banu, 2011; Upahi & Oyelekan, 2020; Mhlanga & Moloi, 2020). The quest to define the role of practical work and its effectiveness continues, however what has been established is that practical work is useful and central in science teaching and learning (Millar, 2008; Banu, 2011; Upahi & Oyelekan, 2020). The main questions answered by this study is how was practical work done and ultimately the study also answered where is practical work done in the remote learning context and beyond. The current learning context invited innovation and creativity in teaching and learning practical work in science education (Hofstein & Lunetta, 1982; Shana & Abulibdeh, 2020). The question of how and where is practical work done is mostly affected by the factor of resources, as in materials or apparatus for conducting the experiments. The rising use of different technologies in their digital and non-digital format make it possible for teaching and learning to happen in different space and time, through innovative and creative thinking (Mishra & Koehler, 2006). This study proved that the factor of lack of the laboratory is not as major as before, any space ranging from the living room, kitchen, outside yard can be the working space for practical work. The design team embraced the opportunities that came with remote learning and designed the practical work in a manner that the kitchen would be a suitable area to conduct practical work. With the remote learning context and the rise in use of digital technologies for learning we see many instructors resorting to alternative practical work in the absence of tradition physical laboratory work in science education curriculum across the world (Bean, 2020; Pols, 2020; Tsakeni, 2021; Leung & Cheng, 2021).

The rethinking of practical in this case answered the how research questions regard science practical work in the context of South Africa in a global world where digital technologies are part of teaching and learning South African education. The research questions asked by this study were answered with the data revealing the design, facilitation and learning of practical work to depict the pedagogical approaches, learning approaches, factors influencing and ultimately painting the picture of both teacher educators and preservice teachers' experiences of teaching and learning practical work respectively.

The teacher educators were completely in control of the design of the practical work, where their pedagogical choices included ensuring students remain hands-on with materials to construct science knowledge and understanding scientific processes even though students were in their various residences with no access to laboratory and the much relevant or designated science apparatus. These actions were found to have been influenced by the knowledge that South African ordinary schools still remain largely traditional in their approach to teaching and learning regardless of the rapid digitisation that was also accelerated by the COVID-19 pandemic regulations. Additionally, teacher educators saw the need in having students to also visualise the science phenomenon as they physically observe for measuring and recording of their findings. Moreover, teacher educators saw the need for students to be hands-on due to their prior experiences with having students engage with simulations for practical work.

While they were quite satisfied with the design of the practical work under the situation, what they were unsatisfied with was the feeling of uncertainty of whether students were doing the work as they prescribed it. This is an issue they seem to have overlooked in the rethinking of practical work as there is evident lack of the teaching plan for this designed practical work. This implied teacher educators' autonomy was crippled as they were limited in terms of overseeing the learning process. They rather relied on students' questions of clarity during the discussion sessions which saw little participation or engagement and also their evidence in terms of pictures or videos in what they were really doing in their kitchens. The current study did not focus on assessment, as assessment is such a critical aspect of teaching and learning and it requires extensive deliberation which can be a whole study on its own. Assessment, though spoken about during the interviews, it is not reflected upon in the write up of this study. However, it would have been a great add to the research to look into it, especially with the provision of evidence of what students did with materials. The evidence of what students did with the materials for the practical work activities contributed towards their learning assessment which also served as an indicator that they actually did the practical work as prescribed in the lab manuals.

The learning process was more student-regulated with student directing their actions towards science knowledge construction. Students in the comfort of their residences had to conduct the practical work following the given "recipe" practical work manual, however, they had the opportunity to improvise with material and the opportunity to choose various other learning resources to inform their knowledge construction. Their learning conditions and context gave them more will and power to use digital tools to find relatable content for learning science concepts and processes. Due to limited opportunity to collaborate and engage with peers or teacher educators, student teachers used digital science content to confirm the knowledge they were constructing with the improvised materials. It is this regard that learning was more technology mediated than teacher mediated where the available assistance of teacher educators was not primarily what the students would use for learning. They found tutor support to not be effective as such found digital content to be good confidence boost for confirming the knowledge they were creating. This approach is found at core to limit critical engagements, which also means limited critical knowledge creation, where students are more concerned with just visualising, confirming science concepts and processes as is the general aim of doing science practical work.

However, for teacher education this process also proved to have students engage for learning beyond visualisation and confirming science concepts and processes. It is found, however that students' autonomy was practiced which has implication on the cognitive developments as prospect teachers. Their creative and innovative thoughts as prospect science teachers in South African seem to have been invoked as they made contributions into how and where science practical work to be done. Participants in general believe so much in hands-on practical work which can be supplemented with computer simulations or video analysis. It is well noted by participant that SA school science practical work is influenced by lack of resources, therefore the vision of improvised materials is one of the solutions amongst others as it is quite important to have students engage in practical work.

6.6. Recommendations: implications for research and teaching & learning

The study brings a snippet of possible reality for teaching and learning of physics practical work in south African ITE, it then suggests for research to be on a quest to unearth the actual reality as innovation and creativity through the inevitable change proves to be the order of the rethinking process and even more abruptly due to continued technological advancement accelerated by COVID-19 pandemic era (Mhlanga & Moloi, 2020). For a country whose Higher Education and Training Department's mandate is set to also embrace blended learning, the findings call for further research into innovation and technology mediated teaching and learning of practical work in physics and perhaps other science subjects across South African ITE and schools to build rich internal knowledge base to inform teaching and learning of the country. From literature review in this study and the findings of this study, it is apparent that there is a need for an on the ground research to capture realities of ITE preparation of science teachers to teach practical work in the ever-changing world.

While change is inevitable, factors such as lack of resources continues to prevail as limiting factors for teaching and learning. As revealed in the findings of this study limited resources for conducting practical work had an impact on how the preservice teachers learned practical work. The preservice teachers had to be very creative and compromise at times and also use some digital tools to mediate their own learning. The three interviewed preservice teachers including their colleagues as they shared in their various WhatsApp groups proved to have different but similar experiences with the learning of the intended practical work. they were disadvantaged by one thing or the other, at most the preservice teachers who where further from campus residences were mostly disadvantaged by the resources factor. As such suggesting that in their design phase the design team did not consider carefully various factors such as the students' geographical location, socioeconomic background, and many other factors. This finding then suggests the need to research how teachers unpack the concept of inclusive education for epistemological access when they decide on learning materials and resources for their students as they work around changing their pedagogies for changing times.

The findings of study also drive research towards establishing knowledge base for rethinking of teaching and learning strategies and pedagogies for the science teacher preparation and training. As highlighted in the literature review, scholars in the South African based studies alluded to the point that teachers are not adequately trained to teach practical work in secondary schools and that teachers lack the necessary knowledge and skills to teach practical work (Mogofe & Kibirige, 2013; Oguoma, 2018; Tsakeni, 2018; Gudyanga & Jita, 2019). This study reveals the need for Science ITE instructors to reinvent their teaching pedagogies and strategies to keep the courses relevant through the change, bearing in mind the objectives of the local, regional and global education goals. The approach to teaching practical work in this course reveals some of the key issues affecting practical work infusion in SA secondary school science education, which is really not new to science practical work research. And the findings suggest a further study to check for validity and viability of the approach taken by design team in teaching practical work through an intervention strategy in South African institutions of higher learning so that a model can be formulated to contribute towards developing innovative, creative, adaptable and flexible science teachers in the ever-changing world.

While the study presents more recommendations about researching teaching and learning of practical work for ITE, further recommendations can be made about implications to learning of practical work in classroom. More especially, talking to the kind of student and course instructor for the current classroom setting. The current world operations call for open mindedness that is flexibility and adaptability from both adults and young ones and so is the current teaching and learning conditions (Kivunja, 2015). This study also reveals that for the remote learning context and beyond, flexibility and adaptability are some of the core skills for the teaching and learning. As revealed in this study that students' agency and will are some of the key factors for learning practical work, the current teaching and learning context requires both instructors and students to be flexible, adaptable and open minded. And those are some of the skills in addition to innovation and creativity that need to be harnessed through the curriculum for both teacher education and even for learners in the science classroom. That is because teaching and learning materials for science practical work are no longer rigid and stuck to the idea of a science physical or even virtual laboratory or a computer simulation.

6.7. Limitations

The data collection methods used in this study were enough to depict a detailed picture of how teacher educators went about rethinking practical for their students in the remote learning conditions and it also presented a picture of how learning unfolded for the students. In addition to interviews and documents analysis, observations of the actual practical work sessions would have granted me as a researcher richer and strong stance and voice to discussing the findings. The triangulation process happened through stakeholder interviews, each stakeholder conversation painted a picture of the intended and the enacted practical work, the experiences from each stakeholder group, as well as factors affecting their teaching and learning. The interview conversations together with document analysis allowed a strong triangulation however, the observations would have sealed the final deal and presented me as the researcher a platform to connect the puzzle pieces to depict exactly how the facilitation occurred. In any case the WhatsApp platform used for practical work did not allow proper and full observation as there was really limited participation from the preservice teachers. I wished to have observed the two kinds of sessions spoken of myself and had the first-hand experiences, especially on patterns of engagements during the practical work session. So that I can have critical engagement with the findings and the literature in turn develop a stronger perspective about students' engagement in technology mediated learning as a 21st century researcher. I am particular on students' engagement because it came out strong as all interviewed participated reflected on it, which also touch on issues of students' autonomy and confidence in their knowledge construction processes as they learn. It also links with teacher action in practice in a student-centred or student regulated learning tasks. And all these are some of the major findings in this study.

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X. Appendices

Appendix A

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Moabelo

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H21/10/28**
PROJECT TITLE	Physical Science Teacher Education: Rethinking practical work
INVESTIGATOR(S)	Miss T Moabelo
SCHOOL/DEPARTMENT	Wits School of Education/
DATE CONSIDERED	22 October 2021
DECISION OF THE COMMITTEE	Approved Risk Level: Minimal
EXPIRY DATE	30 November 2024

DATE 01 December 2021 **CHAIRPERSON** J Knight
(Professor J Knight)

cc: Supervisor : Prof E Mushayikwa and Prof S Zulu

Appendix B:

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

WSoE Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
Tel, +27 11 717-3049 • Fax: +27 11 717-3009 • Website: www.wits.ac.za

Lab demonstrators' Consent Form

Title of project: Physical Science Teacher Education: Rethinking Practical Work

Name of researcher: Tshegofatso Moabelo

I, ..., agree to participate in this research project. The research has been explained to me and I understand what my participation will involve. I agree to the following:

(Please circle the relevant options below).

I agree that my participation will remain anonymous	YES	NO
I agree that I will participate in an interview that the researcher will schedule with me prior the actual interview	YES	NO
I agree that the researcher may use anonymous quotes in his / her research report	YES	NO
I agree that the researcher may have access to the pre-recorded lesson, observe and analyse it	YES	NO

TSHEGOFATSO MOABELO 0723996100,
1259476@STUDENTS.WITS.AC.ZA
OFFICE B253D

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
Tel, +27 11 717-3049 • Fax: +27 11 717-3009 • Website: www.wits.ac.za

I agree that the information I provide may be used in an anonymized format after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.	YES NO
I agree that the interview will be recorded	YES NO

Informed Consent I understand that:

My name and information will be kept confidential and safe and that my name and the name of university will not be revealed.

I do not have to answer every question and can withdraw from the study at any time

I can ask not to be audio recorded, photographed and/or video recorded All the data collected during this study will be destroyed within 3-5 years after completion of this research project.

.... (signature)
.... (name of participant)
.... (date)

...............T. Moabelo............... (signature)
Tshegofatso Moabelo__________ (name of person seeking consent)
23- September- 2021____________ (date)

TSHEGOFATSO MOABELO 0723996100,
1259476@STUDENTS.WITS.AC.
ZA OFFICE B253D

Appendix C

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
Tel, +27 11 717-3049 • Fax: +27 11 717-3009 • Website: www.wits.ac.za

Student teachers' Consent Form

Title of project: Physical Science Teacher Education: Rethinking Practical Work

Name of researcher: Tshegofatso Moabelo

I, ………………………………, agree to participate in this research project. The research has been explained to me and I understand what my participation will involve. I agree to the following:

(Please circle the relevant options below).

I agree that my participation will remain anonymous	YES	NO
I agree that I will participate in an interview that the researcher will schedule with me prior the actual interview	YES	NO
I agree that the researcher may use anonymous quotes in his / her research report	YES	NO
I agree that the researcher may have access to the pre-recorded lesson, observe and analyse it	YES	NO

TSHEGOFATSO MOABELO 0723996100,
1259476@STUDENTS.WITS.AC.ZA
OFFICE B253D

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

WSoE Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
Tel, +27 11 717-3049 • Fax: +27 11 717-3009 • Website: www.wits.ac.za

I agree that the information I provide may be used in an anonymized format after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.	YES	NO
I agree that the interview will be recorded	YES	NO

Informed Consent I understand that:

My name and information will be kept confidential and safe and that my name and the name of university will not be revealed.

I do not have to answer every question and can withdraw from the study at any time

I can ask not to be audio recorded, photographed and/or video recorded All the data collected during this study will be destroyed within 3-5 years after completion of this research project.

……………………………(signature)
……………………………(name of participant)
……………………………(date)

……….T. Moabelo……….(signature)
Tshegofatso Moabelo________(name of person seeking consent)
23- September- 2021_________(date)

TSHEGOFATSO MOABELO
0723996100,
1259476@STUDENTS.WITS.AC.ZA
OFFICE B253D

Appendix D

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
Tel, +27 11 717-3049 • Fax: +27 11 717-3009 • Website: www.wits.ac.za

Teacher Educator's Consent Form

Title of project: Physical Science Teacher Education: Rethinking Practical Work

Name of researcher: Tshegofatso Moabelo

I, ………………………………, agree to participate in this research project. The research has been explained to me and I understand what my participation will involve. I agree to the following:

(Please circle the relevant options below).

I agree that my participation will remain anonymous	YES	NO
I agree that I will participate in an interview that the researcher will schedule with me prior the actual interview	YES	NO
I agree that the researcher may use anonymous quotes in his / her research report	YES	NO
I agree that the researcher may have access to the pre-recorded lesson, observe and analyse it	YES	NO

TSHEGOFATSO MOABELO
0723996100,
1259476@STUDENTS.WITS.AC.ZA

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa
Tel, +27 11 717-3049 • Fax: +27 11 717-3009 • Website: www.wits.ac.za

I agree that the information I provide may be used in an anonymized format after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.	YES	NO
I agree that the interview will be recorded	YES	NO

Informed Consent I understand that:

My name and information will be kept confidential and safe and that my name and the name of university will not be revealed.

I do not have to answer every question and can withdraw from the study at any time

I can ask not to be audio recorded, photographed and/or video recorded All the data collected during this study will be destroyed within 3-5 years after completion of this research project.

……………………………(signature)
……………………………(name of participant)
……………………………(date)

…………T. Moabelo…………(signature)
Tshegofatso Moabelo________(name of person seeking consent)
23- September- 2021__________(date)

TSHEGOFATSO MOABELO
0723996100,
1259476@STUDENTS.WITS.AC.ZA
OFFICE B253D

Appendix E

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa Tel, +27 11 717-3049 • Fax: +27 11 717-3009 • Website: www.wits.ac.za

Information sheet for Lab demonstrators

Title of project: Physical Science Teacher Education: Rethinking Practical Work

Dear Sir / Madam

My name is Tshegofatso Moabelo, and I am a M. Diss student in the School of Education at the University of the Witwatersrand, Johannesburg. As part of my studies, I must undertake a research project, and I am investigating the design, implementation, and the learning of physics practical work in the science teacher education. The aim of this research project is to find out, explore and understand the online tailored teaching and learning of physics practical work to 3rd and 4th year pre-service science teachers.

As part of this project, I would like to invite you, as the Physics III Lab demonstrator to take part in an interview. This activity will involve answering a set of questions I have put together, and it will require that you provide me with documents you use for practical work, these are course outline and practical work outline document, students' scripts in the categories: High, moderate and low performing students, and any other information you may have regarding the practical work carried and will take approximately 45minutes – 1hours. With your permission, I would also like to audio record the interview using a digital device. This recording will be stored in my google drive account and only I will have access to this recording. It will be deleted after 5 years after this study is completed and I have been granted with the master's degree. I would like to request for access to your pre-recorded practical work session for observation and analysis.

There will be no personal costs to you if you participate in this project, you will not receive any direct benefits from participation but there are no disadvantages or penalties if you do not choose to participate or if you withdraw from the study. You may withdraw at any time or not answer any question if you do not want to. The interview will be completely confidential and anonymous as I will not be asking for your name or any identifying information, and the information you give to me will be held securely and not disclosed to anyone else. I will be using a pseudonym (false name) to represent your participation in my final research report. If you experience any distress or discomfort at any point in this process, we will stop the interview or resume another time.

TSHEGOFATSO
MOABELO 0723996100,
1259476@STUDENTS.WITS.AC.Z
A OFFICE B253D

27 St Andrews Road, Parktown, Johannesburg, 2193 • Private Bag 3, Wits 2050, South Africa Tel, +27 11 717-3049 • Fax: +27 11 717-3009 • Website: www.wits.ac.za

If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you. The data collected from this research project will be stored in google drive and will be kept for 5 years. With your permission the data collected from this research project may be used by other researchers in an anonymized format. If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non Medical), telephone +27(0) 11 717 1408, email hrecnon-medical@wits.ac.za

Yours sincerely,
Tshegofatso Moabelo
1259476@studnets.wits.ac.za
0723996100

Supervisor (s):
Dr Emmanuel Mushayikwa,
Emmanuel.mushayikwa@wits.ac.za
0822615818
Sphamandla Zulu
Sphamandla.zulu1@wits.ac.za
0785493480

Appendix F: Reliability check, the coding process

Research Topic: Rethinking Practical Work in the Digital Era: A Physical Science Teacher

Education Case Study

1.6. Research questions

The current study seeks to answer the following research question: How does the physics III course respond to practical work in science teacher education in the online teaching and learning mode?

To guide this study and answer the research question, the following sub-research questions were conceptualised.

1. What kind of practical work is engaged in the Physics III teacher education course during online learning?

2. What are physics teacher educators and physics pre-service teacher educators' experiences of designing, implementing, monitoring, evaluating, and participating in an online practical work?

3. What are the factors affecting the teaching and learning of physics III practical work designed for online learning?

Zwai (Student number 3 interview transcript, QA'd)

OK cool so we don't need cameras on for ethics purposes I don't think I will have time to blare everything. It so we can just talk. OK I have my questions with me and I'm going to start with the interview and the first question I'd like to ask... I've just put some categories to this and this are just contextual questions I just want to get your background on engagement with physics practical work as a learner and as a student and maybe you're familiarity with computers or the digital devices so that I can just get a sense of where you are in terms of it.

Michelle: so, the first question would be, did you have physical science as one of your subjects in high school or you just doing it in in this program the teacher education program?

Zwai: no, I did from grade 10

Physics in High School

Michelle: did you have physics practical work or how did the teacher approach this aspect of teaching physics in high school?

Zwai: the disadvantage was the lack of resources so it was a matter of having, if we are doing practical maybe an experiment then the teacher will just come with the textbook for example the Siyavula textbook has the recommended experiment and also the answers so we just coping what the textbook is saying and that was it

Access to/engagement with physics practice at high school/

Michelle: so, there was no way where you were conducting these experiments yourself or your teacher maybe conducting them in front of you guys?

Zwai: No, except for when we were in grade 11 we did newton's second law but it was because there was a tutorial program that was supplying the materials so if that tutorial program was not around then we would have not even done that

engagement with physics practice at high school

2

Michelle: was it the same experience even in grade 12?

Zwai: yes,

Michelle: so how was practical work connected during your first and second year of this program that you're in right now?

Zwai: yeah, first year we went to the labs and yeah, the tutors tried to show us and tried to learn the names and how to use the apparatus but it was so difficult because to some of us especially me I felt like these things are new and yet we supposed to know them even from high school. so yeah, it was interesting but also difficulty experience because there are resources, but we are we are unable to use them, so the tutors had to actually start us from scratch teach us the names and what each does and that

engagement with Physics practice at university

Michelle: so, before we get to the online laboratory that you are doing now, the online practical activities I just want to understand your sense of how you use the digital devices and network coverage in your area

Michelle: So, what device do you use for learning?

Zwai: I use a laptop

digital access

Michelle: is it allowing you to actually get through with the particular practical activity that you were given

Zwai: as long as like there's network and this year, I was living on campus so I had no issues with data or network is just working fine

digital access

Michelle: OK in terms of computer skills, how bad or how good are you in terms of computer skills with 10 as excellent and zero as bad

Zwai: alright I can save 5 because there are things that are still cannot do, like setting up a meeting I tried to set up a meeting on teams and then I couldn't so we had to use Google meetings as an alternative and even excel because we learned it first year, there is a course where we learned about them but because we didn't use them so the knowledge just went away

digital readiness

Michelle: OK so are you able to access and efficiently navigate through all apps or the site that you use for learning this particular work or learning physics in general

Zwai: yeah, I am

digital readiness

Michelle: and on a scale of 10, with 10 excellent and zero as bad how is coverage in your area where you hold your lessons

Zwai: It was fine, and I mean I was on campus so I would give a 10

digital access

Michelle: alright so how often do you connect to the Internet maybe for the entire lesson without any disturbances at all or do you normally have disturbances whether it's network or maybe the site that you use for learning just goes down?

Zwai: I think it happened almost 50% of the time because Ulwazi the site we use for lectures sometimes just does not want to work and sometimes it has sound problems where mics do not work, and we have to move to teams and sometimes it is electricity issues which affect the network.

digital access

gh

Appendix G

Interview guide with consultant.

Background knowledge on engagement with physics

1. Are you a BSc physical sciences major or a B. Ed physics major?
2. If a BSc physical science major, do you have any qualification in physical science education/teaching.
3. How long have you been a physics teacher educator?

Digital devices uses and network coverage

1. What device do you use to prepare the working document? (Tick applicable option(s))
    - Smart phone
    - Desktop
    - Laptop
    - Tablet
    - Other, please specify…………………………………
2. Elaborate more on your role in the physics 3 course?
3. What kind/form of practical work do you plan and give to your students?
4. What informed this form practical activity?
5. Are there any apps/sites that you use to design to create the activities (to present the visuals/ graphic representations)/ digital content perhaps used to guide your activity design?
6. What teacher knowledge informed your choice of the app/site used?
7. What digital content do you use to inform your science knowledge that the activity is trying to teach students?
8. What apparatus do you require from students to successfully complete the activities?
9. What informs the choice of apparatus for each activity? (you can ask what is the different between them and usual physics lab apparatus?)
10. How do you account for the shortfalls of the materials the students might use and how are students informed about them and how are they accounted for in assessment?
11. What form or template of science practical report do you require from the students? What informs this choice?
12. How does is it limit/allow students to learn the intended science concepts?
13. What platform is used for the facilitation of practical work?
14. How do you think this platform allow or limit the successful facilitation of practical activity?
15. What informed this choice?
16. Did you have a guideline on how the designed activities should be facilitated?
17. How are student’s learning context considered when you design the activities?
18. What philosophy guided your understanding practical work, its role and effect in physical science education?
19. What learning experience did you intend for the preservice teachers with the activities
20. How was students’ responses to the practical tasks during the actual activity and from their scripts?

Appendix H

Lecturer Interview

This interview should be done with a Physics III teacher educators in the Science teacher education program. If the lecturer is not available, then the interview should be conducted with their assistant/lab demonstrator.
The course outline, practical work manual, practical work activities and student's marked practical reports.

Interviewer: ……………………………………

Interviewee: ………………………………

Role: ……………………………………………….

Interviewee staff No:……………………

Interview Date: ………………………………

Time: ……………………………………………

Interview number: ……………………………

Consent

This interview will last approximately 45- 60 minutes, depending on how much you have to say. Participation in the interview is voluntary, and you may stop the interview or withdraw consent at any time.

Please feel free to speak openly and honestly. Although no risks outside those humanly possible have been identified with participating in this study, information that you provide during the interview will be treated as confidential and will not be share with anyone else. Identifying information such as the name of the school will be removed when recording.

Please sign below to confirm that you understand the nature and purpose of the study and agree to participate.

Date: ………………………………   Signature: ……………………………………

CONTEXTUAL QUESTIONS

In this section, I want to get a background of your engagement with Physics practical work as a science teacher educator. And I also want to understand your familiarity with computer works and internet connection.

Background knowledge on engagement with physics

1. Are you a BSc physical sciences major or a B. Ed physics major?
2. If a BSc physical science major, do you have any qualification in physical science education/teaching.
3. How long have you been a physics teacher educator?

Digital devices uses and network coverage.

1. What device do you use for teaching? (Tick applicable option(s))
    - Smart phone
    - Desktop
    - Laptop
    - Tablet
    - Other, please specify………………………………
2. On a scale of 10 (with 10 = EXCELLENT and 0 = BAD), how are your computer skills??
3. Are you able to access and efficiently navigate through all the Apps/sites you use for teaching?
4. On a scale of 10 (with 10 = EXCELLENT and 0 = BAD), how is the internet coverage in your area (where you hold your lessons)?
5. Are you able to connect to the internet for the entire lesson without any disturbance/disconnection?
    - Not all the time
    - Most of the times
    - All the time
    - No
6. How does your ability/inability to connect affect your effectiveness in teaching?

Teaching physics practical work online

1. What platform do you use to teach?
2. Did you receive any training on navigating the platforms? If yes, was training narrowed to the teaching of science online or it was a general training on using the platform for teaching?
3. Does your school have an online science laboratory that you use to choose the kinds of practical activities to give to your students?
4. What kind/type of practical work do you give students in the online modality as compared to traditional laboratory practical work?
    - Videos (YouTube etc)
    - Simulations
    - Home experiments
    - Video games
    - Others, please specify………………………………………………….

5. What informs your choice of the type(s) of practical work?
6. What technological/digital/online content do you use to inform your practical activities?
7. What informs your choice of the digital/online content?
8. How much of practical work do you feature in your teaching plan? Please name all practical activities that you planned for the 2021 academic.
9. How many of the planned where you able you able to have the students complete and assess?
10. If not, all were completed, what challenges did you face that resulted to few activities to be successfully completed?
11. If all were completed, what is it that went right?
12. What format of a practical report do you require your students to follow when reporting their findings?
13. Is it different or the same as the format used when conducting traditional lab work?
14. If it is different, how is it different? And what informed your choice of the format used?

Challenges/successes with students concerning practical work sessions.

Appendix I

Lab demonstrators' Interview Guide

This interview should be done with a lab demonstrator in the in the 3rd year Physical Science teacher education program. the lab demonstrator must be a facilitator of physics practical work session, must be a marking demi and well aware of student's engagement during practical sessions. NB//: The course outline, practical work manual, practical work activities and student's marked practical reports.

Interviewer: ……………………………………

Interviewee: ………………………………

Role: …………………………………………….…

Institutional staff/student No: ………………………………

Interview Date: ………………………………

Time: ……………………………………….…

Interview number: ……………………………

Consent

This interview will last approximately 45- 60 minutes, depending on how much you have to say. Participation in the interview is voluntary, and you may stop the interview or withdraw consent at any time.

Please feel free to speak openly and honestly. Although no risks outside those humanly possible have been identified with participating in this study, information that you provide during the interview will be treated as confidential and will not be share with anyone else. Identifying information such as the name of the school will be removed when recording.

Please sign below to confirm that you understand the nature and purpose of the study and agree to participate.

Date: ………………………………   Signature: ………………………………………

CONTEXTUAL QUESTIONS

In this section, I want to get a background of your engagement with Physics practical work as a lab demonstrator. And I also want to understand your familiarity with computer works and internet connection.

Background knowledge on engagement with physics

1. what is you field of specialization?
2. Do you have any qualification in physical science education/teaching?
3. How long have you been a physics teacher educator/ physics lab demonstrator?

Digital devices uses and network coverage.

1. What device do you use for teaching?
   - Smart phone
   - Desktop
   - Laptop
   - Tablet
   - Other, please specify………………………………
2. On a scale of 10 (with 10 = EXCELLENT and 0 = BAD), how are your computer skills??
3. Are you able to access and efficiently navigate through all the Apps/sites you use for teaching?
4. On a scale of 10 (with 10 = EXCELLENT and 0 = BAD), how is the internet coverage in your area (where you hold your lessons)?
5. Are you able to connect to the internet for the entire lesson without any disturbance/disconnection?
   - Not all the time
   - Most of the times
   - All the time
   - No
6. How does your ability/inability to connect affect your effectiveness in teaching?

Teaching physics practical work online

1. What platform do you use to teach?
2. Did you receive any training on navigating the platforms? If yes, was training narrowed to the teaching of science online or it was a general training on using the platform for teaching?
3. What philosophy guides your practical work conceptualisation?
4. What factors contribute to the mode of practical work being implemented?
5. Does your school have an online science laboratory that you use to choose the kinds of practical activities to give to your students?
6. What kind/type of practical work do you give students in the online learning setup as compared to traditional practical work?
7. What teaching or facilitation approach do you take to have student engage about the practical activity on the platform you use? And what inform this approach?
8. How many of the planned where you able you able to have the students complete and assess?
9. If not, all were completed, what challenges did you face that resulted to few activities to be successfully completed?
10. If all were completed, what is it that went right?
11. What format of a practical report do you require your students to follow when reporting their findings?
12. Is it different or the same as the format used when conducting traditional lab work?
13. If it is different, how is it different? And what informed your choice of the format used?
14. What opportunities and constraints does online teaching and learning modality have on planning, execution, monitoring, evaluation of practical work?

Experiences with students concerning practical work sessions.

1. Summarise your experience with facilitating practical work online?
2. How are students responding to the practical activities you give them?

Appendix J

Student Teacher's Interview Guide

This interview should be done with a Physics III preservice teachers in the Physical Science teacher education program. If the lecturer is not available, then the interview should be conducted with their assistant/lab demonstrator. The course outline, practical work manual, practical work activities and student's marked practical reports.

Interviewer: ……………………………………

Interviewee: ………………………………….

Role: ………………………………………………….

Institutional student No: ………………………………

Interview Date: ………………………………

Time: ……………………………………………….

Interview number: ……………………………

Consent

This interview will last approximately45- 60 minutes, depending on how much you have to say. Participation in the interview is voluntary, and you may stop the interview or withdraw consent at any time.

Please feel free to speak openly and honestly. Although no risks have been identified with participation in this study, information that you provide during this interview will be treated as confidential and will not be shared with anyone else. Identifying information such as your name or the name of the school will be removed when reporting.

Please sign below to confirm that you understand the nature and purpose of the study and agree to participate.

Date: ……………………….   Signature: ……………………………………

CONTEXTUAL QUESTIONS

In this section, I want to get a background of your engagement with Physics practical work as a learner/student. And I also want to understand your familiarity with computer works and internet connection.

Background knowledge on engagement with physics

1. Did you have physical science as one of the major subjects at high school level?

Did you engage in physics practical work? If yes, how often and where were the practical activities conducted

1. How were the physics practical activities conducted during your first and second year of study? And how was the experience? (For Physics III students)

Digital devices uses and network coverage.

1. What device do you use for learning? (Tick applicable option(s))
    - Smart phone
    - Laptop
    - Desktop
    - Tablet
    - Other, please specify……………………………….
2. On a scale of 10 (with 10 = EXCELLENT and 0 = BAD), how are your computer skills?
3. Are you able to access and efficiently navigate through all the Apps/sites you use for learning?
4. On a scale of 10 (with 10 = EXCELLENT and 0 = BAD), how is the internet coverage in your area (where you hold your lessons)?
5. How often do you to connect to the internet for the entire lesson without any disturbance/disconnection?
    - Not all the time
    - Most of the times
    - All the time
    - No
6. How does your ability/inability to connect affect your effectiveness in learning?

Learning physics practical work online

1. What is your perception and understanding of practical work in physics as a physics teacher in training? (Probe the role and importance of practical work in physical science education)
2. Does your school have an online science laboratory that you use to conduct the practical activities given?
3. What platform(s) do you use for your physics practical work learning sessions?
4. Did you receive any training on navigating the platforms?
5. What kind of practical work did you conduct in the physics III course?
6. How did the online learning platform allow you to effectively learn practical work or to get the work given done?
7. Does the given practical activity require you to work individually or through collaboration? *(Probe: In a sense where there is individual work … how does the lab demi or the lecturer come in to help you move from a place of not knowing to a place of knowing? and if there a required collaboration with fellow students, how do you guys make it work and how do the lab demi help you in terms of your collaboration)*
8. What scientific skills and knowledge do you gain from the practical work? (How does the practical work you engage in allow you to understand the nature of science?
9. What online content do you use to help you complete the given task? How does the content help you understand the practical task given? If you do not use the online content, who and how do you consult to ensure that you get the help you need?
10. How is practical work facilitated during the online sessions*? (Probe: introduction of the session, objective outlines, dry run of the activity, guided steps of what to do or how to complete the activity successfully; allowance for collaboration with fellow students; peer engagement).*
11. Is it allowing for effective engagement and participation during the session?
12. On a scale of 10 (with 10 being Fastest and 0 being slowest), how fast do you get help when you ask a question/point of clarity during the session?

Challenges/successes with students concerning practical work sessions.

1. What challenges do you come across as you do the work? (Probe: challenges related to understanding what the practical activities requires from them/ problems understanding the content being taught through the activities/ procedural challenges)
2. Are you able to understand the task without the teacher educator or the lab demi assisting? Or do you have to ask for a clarity first?
3. If you do ask for clarity, how do you get assisted?

Appendix K: Practical Manual Sample

PM02.

Practical 2 Investigating a simple pendulum

Reading before the practical Your lecture notes and your student manual for PS III, 1.2 Oscillations. Also Giancoli Chapter 11, Section 11-4

Equipment you need

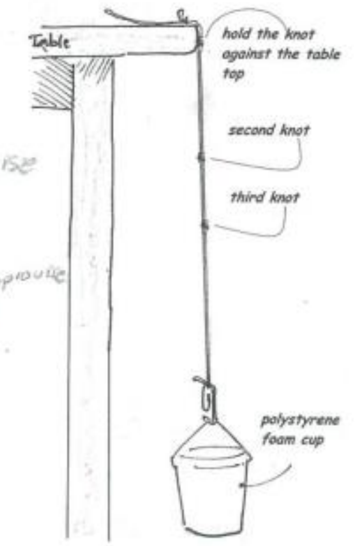
- ❑ ruler or tape-measure
- ❑ string at least 1 m long
- ❑ polystyrene cup
- ❑ dessertspoon
- ❑ water for mass *m*
- ❑ cell phone stopwatch
- ❑ paper-clip

Pendulums have been used in clocks since the 16th century because the period of their oscillation is constant. In Giancoli, Figure 11-13, you see the picture of a swinging lamp that Galileo probably watched; he realised that the period stayed the same even though the amplitude became smaller and smaller.

A Look at Figure 1; this is the simple pendulum that you are going to make. The cup contains a mass and it hangs from a string.

B Put a knot in the string at the position that allows the cup to hang very close to the floor. You will hold the knot with your finger on the edge of the table when the pendulum swings.

Figure 1 *This is what you are going to make.*



C Use the ruler to measure the length of the pendulum, which is the distance from inside the bottom of the cup to the knot. An example of such a length from cup-bottom to knot is 70 cm.

D Prepare to change the length of the pendulum later: put in 2 more knots at, for example, 56 cm and 47 cm from the bottom of the cup. You can choose your own lengths, but measure carefully.

E Answer Question 1, below, before you go on.

F Put 10 dessertspoons of water into the cup; this is your mass in the pendulum. (You could use torch cells, or coins, so long as they are all equal in mass)

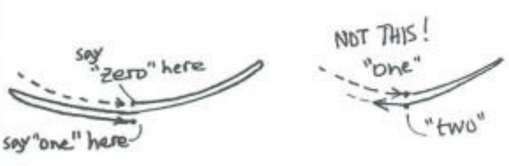
G Pull the cup to one side so that it is about 20° from the vertical; this is the amplitude of the oscillation. Let the cup swing and use your phone stopwatch to measure the time for 10 cycles.

Remember to say "zero!" for the start of the first cycle, and not "one!". A complete cycle is the motion of the cup from the midpoint of the swing, going to maximum amplitude on the right, back through midpoint again, to maximum amplitude on the left and then back to the midpoint. Look at Figure 2.

(In a real lab, demmies would pick up the error that a student counts "one" when releasing the pendulum. If the student does this, when the student says "ten", there have been only 9 cycles.)

H Repeat your measurement of 10*T* to get three readings. Record them as in Question 2 and find the average.

Figure 2 *A complete cycle.*



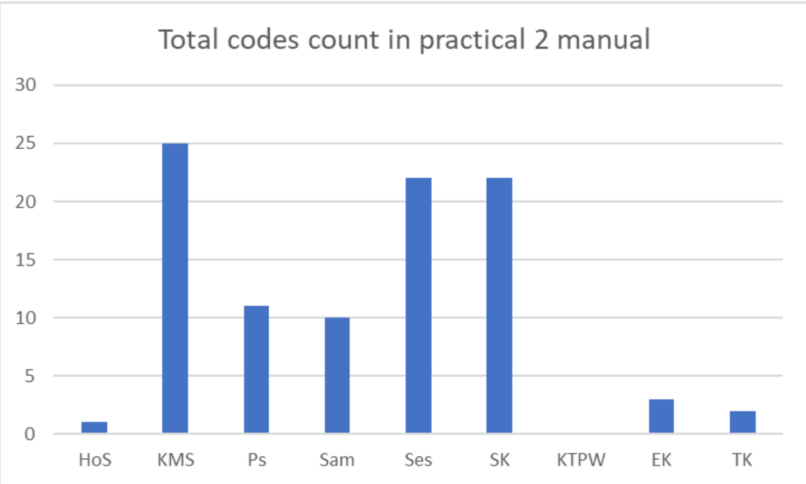
Appendix L: Practical Manual coding process sample

CODE ENTRY	Line numbe	Descrption	code 1	Code 2	Code 3	Code 4	Code 5
PM02	1_2	Reading before the practical Your lecture notes and your student manual for PS III, 1.2 Oscillations. Also Giancoli Chapter 11, Section 11-4	KMS				
PM02	3_7	Pendulums have been used in clocks since the 16th century because the period of their oscillation is constant. In Giancoli, Figure 11-13, you see the picture of a swinging lamp that Galileo probably watched; he realised that the period stayed the same even though the amplitude became smaller and smaller.	SK	HoS			
PM02	8_10	A. Look at Figure 1; this is the simple pendulum that you are going to make. The cup contains a mass and it hangs from a string.	KMS	Sam			
PM02	11_14	B. Put a knot in the string at the position that allows the cup to hang very close to the floor. You will hold the knot with your finger on the edge of the table when the pendulum swings.	KMS	Sam	Ps		
PM02	15_18	C. Use the ruler to measure the length of the pendulum, which is the distance from inside the bottom of the cup to the knot. An example of such a length from cup-bottom to knot is 70 cm.	Sam	SK	KMS	EK	
PM02	19_22	D. Prepare to change the length of the pendulum later: put in 2 more knots at, for example, 56 cm and 47 cm from the bottom of the cup. You can choose your own lengths, but measure carefully.	KMS	Ps			
PM02	23	E. Answer Question 1, below, before you go on.	KMS				
PM02	24_26	F. Put 10 dessertspoons of water into the cup; this is your mass in the pendulum. (You could use torch cells, or coins, so long as they are all equal in mass)	Ps	Sam	KMS		
PM02	27_30	G Pull the cup to one side so that it is about 20E from the vertical; this is the amplitude of the oscillation. Let the cup swing and use your phone stopwatch to measure the time for 10 cycles.	Sam	SK	Ses	TK	Ps
PM02	31_36	Remember to say "zero!" for the start of the first cycle, and not "one!". A complete cycle is the motion of the cup from the midpoint of the swing, going to maximum amplitude on the right, back through midpoint again, to maximum amplitude on the left and then back to the midpoint. Look at Figure 2.	Ses	SK	KMS		
PM02	42-44	H. Repeat your measurement of 10T to get three readings. Record them as in Question 2 and find the average.	KMS	Ses	Ps		
PM02	45_46	I. Use a smaller amplitude, estimated at about 10E from the vertical. Measure 10T three times and find the average of your measurements. See Question 2.	KMS	SK	Ses	Ps	
PM02	47_48	J. Now increase the mass m. Add another 5 spoons of water to the cup to increase the mass m, use the original amplitude of 20Eagain, and measure T. Record T as in Question 3.	KMS	Sam	Ses	Sk	Ps
PM02	49_51	K Change the length l of your pendulum. Hold the second knot on the edge of the table. The pendulum is now, for example, 56 cm long. Using the mass of 15 spoons of water and the original 20E amplitude, measure 10T three times and find the average as in Question 4.	KMS	SK	Sam	EK	Ses
PM02	52_53	L Change the length to the last knot, so that the length is 47 cm, for example. Keep the mass at 15 spoons of water and the 20E amplitude, measure 10T three times and find the average.	KMS	SK	Ps	Sam	Ses
PM02	55_56	1. Several variables could affect the period of the pendulum. Now make some predictions, so that you feel committed to the investigation. You won't lose marks for wrong predictions.	SK	KMS	Ses		
PM02	57	1.1 If you change the amplitude (the angle of the swing), will the period change? ________	Ses	SK			
PM02	58	1.2 If you change the mass at the bottom, will the period change? ________	SK	Ses			
PM02	59	1.3 If you change the length of the pendulum, will the period change? ____________	SK	Ses			
PM02	60	1.4 If you took a pendulum to the Moon, would it have the same period as it did on Earth? ___	SK	Ses			
PM02	63_64	2 Record the measurements of 10 periods T for the amplitudes 20E and 10E, keeping the initial length and mass.	Ses	KMS	SK		
PM02	67_69	The period measurements will show some variation; calculate the average period for each amplitude. Do the changes in amplitude make a difference to the period? Say whether the variations in the measurements are small enough to decide on the answer.	KMS	Ses	SK		
PM02	72_73	3 Record the measurements of 10T for the masses of 10 spoons and 15 spoons of water. Keep your initial length and the initial 20E amplitude.	KMS	Ses	Sam	SK	
PM02	76_78	The period measurements will show some variation; calculate the average period. Do the changes in mass make a difference to the period? Say whether the variations in the measurements are small enough to decide on the answer.	Ses	SK	KMS		
PM02	81_82	4 Record the measurements of 10T for your first, second and third lengths. Keep the mass at 15 spoons water.	KMS	Ses	Sam	Ps	Ek
PM02	85_87	The period measurements will show some variation; calculate the average periods. Do the changes in length make a difference to the period? Are the variations small enough to decide this? If so, what is the relationship?	SK	KMS	Ses		
PM02	89_95	5 As you will learn in this week's lectures, the formula for the period of a simple pendulum is T l g, Just looking at the right side, it's hard to believe that it has the dimension of [TIME] and units of seconds. Do a dimensional analysis and show that the right side has the correct dimension and units. (You can send your answer as a photo. Insert it into your answer sheet.)	SK	Ses	KMS	TK	
PM02	99_100	6 Compare the values of T from the formula, for the three lengths you used, with your measurements of T. Take g as 9.82 m/s	Ses	KMS	Sk		
PM02	105_106	7 Have you noticed that neither amplitude A nor mass m appear in the equation? Make a comment about this fact.	Ses	KMS	Sk		
PM02	118_120	8 If you took the shortest pendulum you made and doubled its length, would you halve or double the frequency or change it by some other factor ? What is the factor? Give a reason for your answer.	SeS	KMS	Sk		

Appendix M: Practical Manual analysis sample (Code count and visualisation)

Codes	Code 1	Code 2	Code 3	Code 4	Code 5	Code 6
HoS	0	1	0	0	0	0
KMS	13	6	5	0	0	1
Ps	1	1	3	2	2	0
Sam	2	4	3	1	0	0
Ses	7	8	5	0	2	0
SK	7	8	5	2	0	0
KTPW	0	0	0	0	0	0
EK	0	0	0	2	1	0
TK	0	0	0	2	0	0

Codes	Total codes count
HoS	1
KMS	25
Ps	11
Sam	10
Ses	22
SK	22
KTPW	0
EK	3
TK	2



Appendix N: Interview transcript memoing ST03

OK cool so we don't need cameras on for ethics purposes I don't think I will have time to blore everything. it so we can just talk. OK I have my questions with me and I'm going to start with the interview and the first question I'd like to ask... I've just put some categories to this and this are just contextual questions I just want to get your background on engagement with physics practical work as a learner and as a student and maybe you're familiarity with computers or the digital devices so that I can just get a sense of where you are in terms of it.

Michelle: so, the first question would be, did you have physical science as one of your subjects in high school or you just doing it in in this program the teacher education program?

Zwai: no, I did physical science from grade 10

Michelle: did you have physics practical work or how did the teacher approach this aspect of teaching physics in high school?

Zwai: the disadvantage was the lack of resources so it was a matter of having, if we are doing practical maybe an experiment then the teacher will just come with the textbook for example the Siyavula textbook has the recommended experiment and also the answers so we just copying what the textbook is saying and that was it

Michelle: so, there was no way where you were conducting these experiments yourself or your teacher maybe conducting them in front of you guys?

Zwai: No, except for when we were in grade 11 we did newton's second law but it was because there was a tutorial program that was supplying the materials so if that tutorial program was not around then we would have not even done that

Michelle: was it the same experience even in grade 12?

Zwai: yes,

Michelle: so how was practical work connected during your first and second year of this program that you're in right now?

Zwai: yeah, first year we went to the labs and yeah, the tutors tried to show us and tried to learn the names and how to use the apparatus but it was so difficult because to some of us especially me I felt like these things are new and yet we supposed to know them even from high school. so yeah, it was interesting but also difficulty experience because there are resources, but we are we are unable to use them, so the tutors had to actually start us from scratch teach us the names and what each does and that

Michelle: so, before we get to the online laboratory that you are doing now, the online practical activities I just want to understand your sense of how you use the digital devices and network coverage in your area

Michelle: So, what device do you use for learning?

Zwai: I use a laptop

Michelle: is it allowing you to actually get through with the particular practical activity that you were given

Zwai: as long as like there's network and this year, I was living on campus so I had no issues with data or network is just working fine

glish (United States)   Accessibility: Investigate

Appendix O: Coding and thematic formation for ST03 (Sample)

Line number	*Zwai's initial Code*	COUNTA of Zwai's Code	Axial codes	Themes
183-184	I did random search for information	1	use of digital tools for conceptual understanding	Digital technologies and use for teaching and learning practical work
178-181	I read some documents on google to enhance my conceptual understanding	1	use of digital tools for conceptual understanding	Digital technologies and use for teaching and learning practical work
102-208	I use the PhET simulation to visualise the concepts	1	use of digital tools to visualise concepts	Digital technologies and use for teaching and learning practical work
35	I used my laptop	1	use of digital device	Digital technologies and use for teaching and learning practical work
95-98 102-108	I used the PhET simulations to enhance my conceptual understanding	2	use of digital tools for conceptual understanding	Digital technologies and use for teaching and learning practical work
178-181 189-193 195-196	I watched some YouTube videos to enhance practice and conceptual understanding	3	use of digital tools for conceptual understanding	Digital technologies and use for teaching and learning practical work
74-80	we had WhatsApp groups	1	use of digital tools for communication and engagements	Digital technologies and use for teaching and learning practical work
123-140	seeing conceptualisation through the simulations made it interesting	1	use of digital tools for conceptual understanding	Digital technologies and use for teaching and learning practical work

102-208 123-140 224-236 247-256	accuracy was compromised due to improvising with materials	4	In/availability of Sam	Opportunities and Limitations to teaching and learning practical work
61-66	all this session disturbance affects one's interest in the lesson	1	Technical Glitches: Loss of interest	Opportunities and Limitations to teaching and learning practical work
154-156	conducting the practical work at home was interesting	1	Interesting KTPW	Opportunities and Limitations to teaching and learning practical work
334-344	I consulted with the prescribed information sources	1	Student Agency	Opportunities and Limitations to teaching and learning practical work
38-39 51	I did not have network issues as I was staying on Campus	2	Internet connection	Opportunities and Limitations to teaching and learning practical work
239-245	I had to compromise and use unprescribed materials	1	In/availability of Sam	Opportunities and Limitations to teaching and learning practical work
247-256	most of us were disadvantaged by improvised materials	1	In/availability of Sam	Opportunities and Limitations to teaching and learning practical work
55-57	Power cuts sometimes disturbed the sessions	1	Power cut	Opportunities and Limitations to teaching and learning practical work
74-80 144-156	Practical work and tutorials session were not effective because of time constraints	2	Ineffective PW/Tutorials sessions	Opportunities and Limitations to teaching and learning practical work
267-183	sometimes misconceptions go uncorrected	1	Lack of knowledge management/Limited engagements	Opportunities and Limitations to teaching and learning practical work
74-80	students had to consult with tutors for clarity	1	Lecturer/tutor availability for enquiry	Opportunities and Limitations to teaching and learning practical work
224-236	Students who stayed far from campus did not have access to correct materials	1	In/availability of Sam	Opportunities and Limitations to teaching and learning practical work
55-57	Technical glitches-ULS	1	Technical glitches	Opportunities and Limitations to teaching and learning practical work
267-283	there is limited engagements online	1	Limited engagements	Opportunities and Limitations to teaching and learning practical work
154-156 202-218 224-236 334-344	tutor support was ineffective online	4	Ineffective tutor support	Opportunities and Limitations to teaching and learning practical work
321-329	we have PW briefing sessions with the lecturer	1	Lecturer/tutor availability for enquiry	Opportunities and Limitations to teaching and learning practical work
74-80 144-156	whatsapp hindered effective engagements	2	Limited engagement	Opportunities and Limitations to teaching and learning practical work

286-196	I have realised that there are some PW that you cannot compromise	1	The emphasis on the importance of practical work	Perception to teaching and learning practical work
286-296 300-315	I learnt that as science teachers we can be innovative and creative	2	21st century skills: Creativity and innovation	Perception to teaching and learning practical work
267-283	Physical PW allows for preparation	1	The importance of Traditional lab practical work: for learning approach	Perception to teaching and learning practical work
267-283	Practical work need to happen physically for collaborative work to be efficient	1	The importance of Traditional laboratory work	Perception to teaching and learning practical work
286-296	we need to still teach learners scientific skills	1	The importance of hands-on	Perception to teaching and learning practical work

167-168	I gained some scientific skills	1	I gained scientific skills	Practical work design for teaching and learning practical work
159-165	I preferred working alone	1	Individual work	Practical work design for teaching and learning practical work
102-108	It is difficult to understand the concepts from just note	1	Limited information/notes	Practical work design for teaching and learning practical work
112-120 334-344	It was interesting to see the concepts through the materials	2	SK	Practical work design for teaching and learning practical work
84-88	practical work brings reality to the scientific concepts	1	PW visualise the concept.	Practical work design for teaching and learning practical work
84-88	practical work teaches students scientific skills and processes	1	The importance of attaining scientific skills	Practical work design for teaching and learning practical work
84-88	practical work visualise the concepts for students	1	PW visualise the concept.	Practical work design for teaching and learning practical work
321-329	safety precautions are not stressed for AHPW	1	Simple practical work	Practical work design for teaching and learning practical work
224-236	some of the instructions were not so clear	1	Unclear PI	Practical work design for teaching and learning practical work
159-165	some students worked together to conduct the practical work	1	Peer to peer collaboration	Practical work design for teaching and learning practical work
348-350 352	the evaluation had no guiding feedback	2	Unfair assessment practices	Practical work design for teaching and learning practical work
159-165	The practical activities were meant for individual submission	1	Individual work	Practical work design for teaching and learning practical work
112-120 123-140	The practical work was aligned to the content	2	Sku	Practical work design for teaching and learning practical work
69-71	We conducted our practical work at home	1	KTPW	Practical work design for teaching and learning practical work
	We had to find simple accessible materials	1	Sam	Practical work design for teaching and learning practical work
69-71	we had to submit evidence of how we connected our materials	1	Evidence-based	Practical work design for teaching and learning practical work
170-173	we were provided with a worksheet to answer some questions	1	Pedagogic approach	Practical work design for teaching and learning practical work

9	I did Physical sciences since High school	1	Prior Exp: Unfamiliarity with Lab materials	Prior experience about teaching and learning practical work
25-30	I had difficulties using laboratory apparatus	1	Prior Exp: Unfamiliarity with Lab materials	Prior experience about teaching and learning practical work
260-264	I had good experience of practical in the laboratory as compared to the at home PW	1	Enjoyed traditional lab PW	Prior experience about teaching and learning practical work
12-15	my high school teacher would read the practical work task for us	1	Prior Exp: poorly resourced schools	Prior experience about teaching and learning practical work
12-15	Our school lacked the resources for practical work	1	Prior Exp: poorly resourced schools	Prior experience about teaching and learning practical work
25-30	there was support from the tutors in first year	1	Prior Exp: effective tutor support	Prior experience about teaching and learning practical work
25-30	we had laboratory sessions in first year	1	Prior Exp: Laboratory sessions	Prior experience about teaching and learning practical work
18-20	We only did practical work through another tutorial program that came to our school	1	Prior Exp: partially familiar with practical work	Prior experience about teaching and learning practical work
381-393	Even if it is not for online learning, we need to contextualise physical science for SA	1	The need for a context bound virtual lab	Recommendations to teaching and learning practical work
364-378	If we are to go online we must be context sensitive	1	The need for a context bound virtual lab.	Recommendations to teaching and learning practical work
364-378	We need a physical science dictionary for SA learners	1	The need context bound Science dictionary.	Recommendations to teaching and learning practical work
360-362 364-378	We need SA context specific simulations for online learning	2	The need for a context bound virtual lab.	Recommendations to teaching and learning practical work