Investigating the effectiveness of a blended professional development intervention in improving the teaching of Physical Sciences: A study of novice teachers in South African rural schools

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LIST OF ABBREVIATIONS

Abbreviation	**Term in full**
CDE	Centre for Development and Enterprise
DBE	Department of Basic Education
HEI	Higher Education Institution
HRDC	Human Resource Development Council
LCT	Legitimation Code Theory
LOLT	Language of Teaching and Learning
MEC	Member of the Cabinet
PAM	Personnel Administrative Measures
PCK	Pedagogical Content Knowledge
PED	Provincial Education Department
PLM	Pedagogical Link Making
SADC	Southern African Development Community
SCK	Subject Content Knowledge
SMT	School Management Team
TPCK/TPACK	Technological Pedagogical Content Knowledge

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To God almighty, all of this would not have been possible if not for you. Thank you, Lord.

DECLARATION

I know and accept that plagiarism is DISHONEST. Therefore, I declare that:

- ✓ This research dissertation is my own work.
- ✓ I have acknowledged all direct quotations and paraphrased ideas.
- ✓ I have provided a complete, alphabetized reference list, as required by the APA method of referencing.
- ✓ I have not allowed and will not allow anyone to copy my work with the intention of passing it off as his or her own work.
- ✓ I 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 source of the ideas or words in my writing.

Full Name: Nomfundo Knowledge Radebe

Signature: N.K. Radebe.

Date: 27 June 2024

PREAMBLE

Growing up and living in rural areas of the Mpumalanga province, I have witnessed the unique teaching and learning challenges experienced in these communities. This experience has been further informed by my experience as a tutor, bearing first witness to the challenges that first year students face when pursuing their teaching qualification in science education. For example, some students I have tutored were from rural areas and during the induction to laboratory material in first year undergraduate science course, I would observe that they had never seen a test tube or beaker and did not know how they look like. They would also take long to complete any experiment and struggle to write laboratory reports. I sympathise with these students because I had a similar experience. These experiences have profoundly shaped my understanding of the educational landscape and have motivated me to pursue research in the professional development of teachers, particularly in rural areas. The significance of this research lies in its potential to unearth the specific needs of teachers who often work with limited resources, face geographic isolation, and must adapt to diverse teaching contexts. It also highlights components that have the potential to effectively shape teaching practice and learner outcomes.

While there is substantial literature on professional development, much of it centres on urban and suburban contexts, leaving a gap in understanding the distinctive circumstances of teachers in rural areas. Moreover, evidence shows that professional development initiatives have not been able to achieve much success in shaping teaching practice and learner outcome. With not much professional development opportunities for teachers in rural areas, my interest was aroused when I learned of a study which intended to professionally develop teachers in Mpumalanga (different area from where I grew up). For me, this was an invaluable opportunity to learn about the best practices and/or model to professionally develop teachers, particularly in rural areas as not much adaptation would be required if they were to be applied in another rural context. Also, I wanted to know whether the intervention would be effective and overcome the challenges faced by most professional development initiatives. The focus of my study was particularly on novice teachers as they tend to face countless challenges in adapting to the school environment with little to no support.

Since my personal connection to rural communities has driven me to conduct this study, I may appear too critical in examining the effectiveness of the professional development interviewed examined in this study. However, this is only so it can provide us with best practices that will not only bridge the gap between practice and research, but also improve teaching practice and learner outcomes. By investigating the professional development of teachers in rural areas, this research aims to contribute to the creation of more equitable and effective support systems for teachers. It is hoped that the findings will inform policies and practices that recognize and address the unique needs of rural educators, ultimately improving educational outcomes for learners in these communities.

ABSTRACT

Professional development is a cornerstone in shaping the teaching practice of novice teachers as well as those teachers who are teaching subjects they are not qualified to teach (off-field teachers). However, such support is scarce in rural schools because of the shortage of qualified teachers and geographical constraints, leaving teachers with two options, either to sink or swim, particularly in getaway subjects such as Physical Sciences. This is possible because Physical Sciences has fewer teachers graduating each year and is most likely being taught by off-field and novice teachers due to the lack of desired posts in other schools besides those in rural areas. As such, a blended professional development intervention for Physical Sciences teachers in a circuit consisting of rural schools in Mpumalanga province was administered by another study (referred to as larger study). This province was selected because of the persisting poor performance in Physical Sciences. The intervention was blended because it consisted of online and face-to-face teacher workshops, using the training model from the transmissive category of professional development aimed at transmitting information. The blended nature of the professional development intervention also emanates from the utilisation of WhatsApp, an online tool, to establish a community of practice, promoting collaboration amongst teachers and facilitators.

The aim of the intervention was to shape the teaching practices of the Physical Sciences teachers in the circuit. It was also aimed at helping the teachers improve the performance of their learners by sharing with them skills they can use to prepare their learners for examinations. However, research has shown that professional development initiatives tend to fail to meet their intended objectives, exacerbating the need for its effectiveness to be continuously determined. Given this background, this study examined the effectiveness of the intervention in shaping the teaching practice of novice teachers only due to the challenges they experience as outlined above. The novice teachers were defined as teachers with less than five years of experience teaching Physical Sciences, inclusive of off-field teachers. A total of three novice teachers, out of thirteen Physical Sciences teachers, were available in the circuit and participated in the intervention. Two of these novice teachers (Mr Jones and Mr Smith) were not qualified to teach Physical Sciences unlike Mr Brown. In addition, Mr Smith has been teaching Mathematics for sixteen years and had only two years' experience in teaching Physical Sciences.

To determine the effectiveness of the intervention, the following research questions were answered: (1) What are the teaching and learning needs of novice Physical Sciences teachers in the rural schools of Mpumalanga province? (2) What are the views of the novice Physical Sciences teachers about the effectiveness of the blended professional development intervention workshops? (3) In what ways have the teaching practices of Physical Sciences novice teachers changed after participating in a blended professional development intervention? (4) How were the identified teaching and learning needs of novice Physical Sciences teachers in the rural schools of Mpumalanga addressed by the blended professional development intervention? As such, two lessons per teachers were observed before and after they participated in the intervention. Semi-structured interviews were conducted with the teachers individually before and after participating in the intervention. Furthermore, field notes were written down during the intervention workshops.

Triangulation of data methods and data sources (all collected data) was used to analyse the data in order to determine the teaching and learning challenges of these novice teachers as well as how the identified needs were addressed. The data was organised into two themes, classroom and professional efficacy, sub-categories of teacher efficacy which refer to teachers' own set of beliefs about their capability to successfully perform tasks related to teaching. To determine the views of the teachers about the effectiveness of the blended intervention workshops, patterns from the interviews were sought and categorised into themes. Triangulation of data sources was utilised to strengthen the reliability and validity of the emerging findings by drawing mainly on the written field notes as well as lesson observations collected before and after the intervention. To determine ways in which the teaching practice of these three novice teachers changed, triangulation of frameworks was used to categorise and analyse all the lesson observations. The frameworks used were the knowledge building approach from the pedagogical links making (PLM) framework and semantic codes from the legitimation code theory (LCT). Their lesson observations before the intervention were compared with those conducted after the intervention to note changes, or lack thereof, in the teaching practice of these teachers.

Using the described analysis process, this study found that the blended professional development intervention failed to shape the teaching practice of these teachers. This failure was primarily the result of poor design of the blended professional development intervention. For example, insufficient time was allocated to some topics that were identified as challenging by the teachers.

Additionally, those topics that the majority of the teachers found challenging and needed professional development on were not addressed in the intervention workshops. Furthermore, there was poor attendance in online workshops perpetuated by the lack of active engagement as well as lack of sufficient digital tools, particularly internet data to access the workshops. Moreover, there was lack of individual support in online workshops, which has a potential to promote opportunities of assistance tailor made to the needs of the teachers through coaching and/or mentoring.

Although the intervention did not succeed in shaping the teaching practices of these novice Physical Sciences teachers, it was able to assist them in improving the performance of their learners. This success was because of the explicit focus on this aspect, whereby the strategies to prepare learners to pass the examination were shared with the teachers per topic. Due to improved learner performance, this study noted a newfound confidence in these teachers, particularly Messrs Jones and Brown, resulting in an improvement in their classroom and professional efficacy. As such, this study recommends that professional development initiatives should consider learner performance as a separate entity that requires explicit focus instead of treating it as a byproduct of improved teaching practice. Furthermore, blended professional development interventions must be carefully designed to shape teaching practice by focusing on developing teachers' subject content knowledge and pedagogical content knowledge. It must be informed by the needs and goals of all education stakeholders, be of long duration - not less than twenty hours of contact time, encourage active engagement, provide individual support, make provisions for required digital tools, promote active collaboration and it must be sustainable.

However, Mr Smith did not see any improvement in the performance of his learners. This study attributed this to the attitude Mr Smith has about learners who can take Physical Sciences, thereby affecting his teaching practice. Furthermore, he is not qualified to teach Physical Sciences and showed lack of competence in teaching the Chemistry component of Physical Sciences compared to the other teachers. Therefore, great care should be taken in professional development initiatives to ease such attitudes and provide the required support to all novice teachers with distinct backgrounds.

CHAPTER ONE: INTRODUCTION TO THE STUDY

1.1. BACKGROUND OF THE STUDY

1.1.1. The education system in South Africa

Inequalities in the distribution of resources in schools in South Africa dates back to the apartheid era, where white communities had the best and quality resources compared to the Black communities. It has been more than three decades since the apartheid system was abolished, yet inequalities in the distribution of resources in schools still exists and it is a great concern. This is mainly because it directly influences the provision of quality education.

The South African government has attempted to address this issue by categorizing schools into five quintiles. Quintiles refers to the amount of financial support a school may receive from the government (van Dyk & White, 2019). They are determined by the poverty rate; unemployment rate and literacy rate of the community in which the school is located (van Dyk & White, 2019), which are conditionalities of South African Black and rural communities resulting from the legacy of the apartheid system. According to the Department of Basic Education, DBE (2014), schools within quintile 1 to 3 are non-paying fee schools and receive full financial support from the government while schools within quintiles 4 and 5 are fee-paying schools and these schools receive minimal financial support from the government. In other words, quintile 1 represents a class of schools treated as poorest while quintile 5 represents a class of schools treated as wealthy. Approximately, 60% of the schools in South Africa fall within quintiles 1, 2 and 3, which are schools located largely in rural areas and townships (DBE, 2014).

However, categorising schools into quintiles is insufficient for schools in lower quintiles. This is because, as demonstrated by Caygill et al. (2010), quality teaching depends on the availability of resources that support learning, which includes science laboratory materials and qualified teachers, particularly in gateway subjects like Physical Sciences.

The South African government's approach neglects the availability of teachers who are pivotal in teaching since they are unevenly distributed across the quintiles, as Ogbonnaya and Awuah (2019) observed. Ogbonnaya and Awuah (2019) further observed that schools in lower quintiles have a high teacher-learner ratio resulting in teachers having extensive workload, thereby reducing their effectiveness in teaching. Consequently, learners' performance is negatively affected.

Supovitz and Turner (2000) assert that high teacher-learner ratio has caused teachers from low quintile schools to use more traditional teaching approaches when compared to teachers from high quintile schools. This indicates that there is a shortage in the distribution of teaching and learning resources in low quintile schools, teachers in this case (Ogbonnaya & Awuah, 2019). The shortage in the distribution of resources, as a legacy of the apartheid system, has negatively impacted the performance of learners in these schools. This is evident in Figure 1 below representing schools that have managed to achieve hundred percent for the past five years.

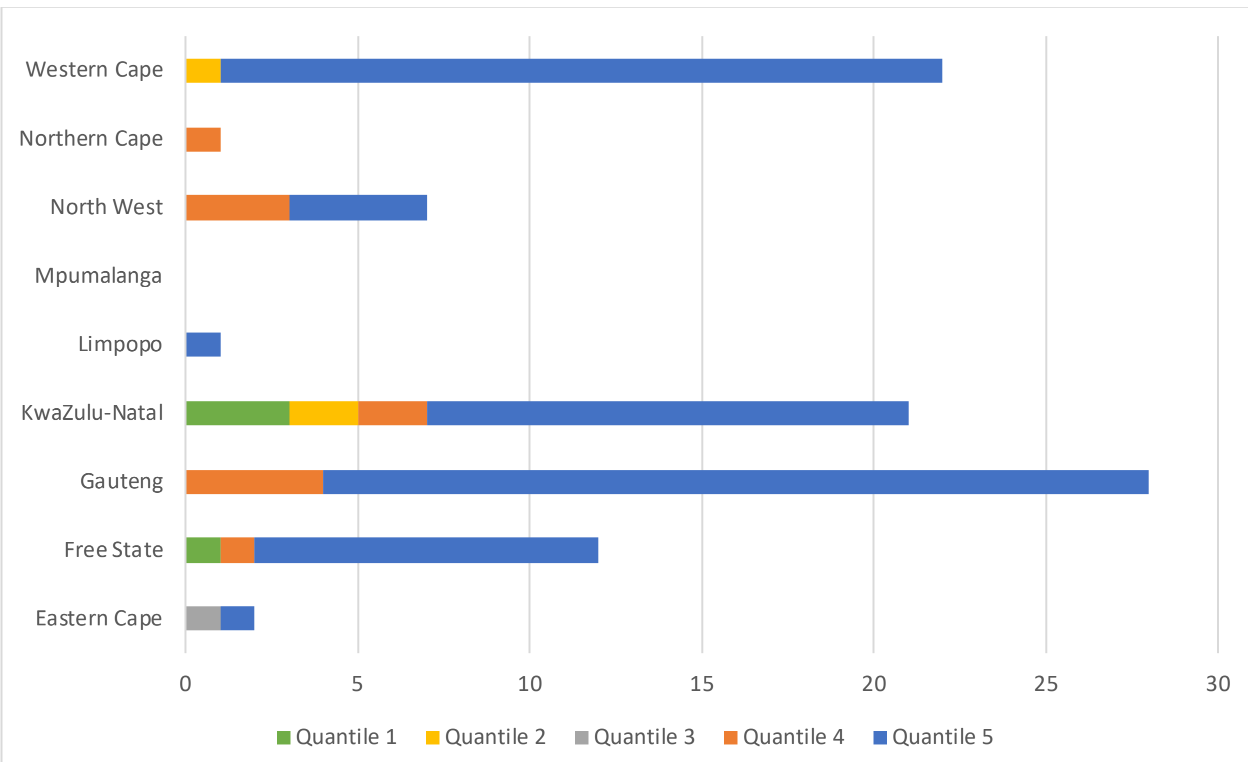


Figure 1: Number of schools that achieved 100% from 2018 to 2022 per province (*Extracted from 2022 National Senior Certificate: School performance report* (DBE, 2023))

South Africa has approximately 6 895 secondary schools (DBE, 2023). Figure 1 above shows that out of 6 895 secondary schools in the whole of South Africa, only ninety-four schools have been able to achieve 100% from 2018 to 2022. Out of the ninety-four schools, only four schools are from quintile 1, three schools from quintile 2, one from quintile 3; eleven schools are from quintile 4; and seventy-five schools are from quintile 5. This means that schools within quintiles 4 and 5 are performing well since they are having a greater share from the ninety-four schools as compared to schools within the lower quintiles. Thus, concurring with Spaull's (2011) and Ogbonnaya and Awuah's (2019) findings that learners in wealthy schools outperform those in poor schools in academic achievement. This observation underscores the underlying challenges faced by schools in quantile 1, 2 and 3 which includes rural schools. As van Dyk and White's (2019) show, schools in low quintiles are associated with education of poor quality. These underlying challenges seem to be severe in the Mpumalanga province. Figure 1 above shows that none of its schools, regardless of the quintile, have managed to achieve a 100% pass rate from 2018 to 2022.

Against this backdrop, the aim of this study was to improve the status quo of rural schools, particularly in Mpumalanga province, by working closely with a larger study[1] that administered a teacher professional development intervention. Professional development is defined as professional learning activities designed to improve the knowledge, skills and understanding of teachers, causing a change in thinking and behaviour in the classroom (Kartal et al., 2019). This study determined the effectiveness of the professional development intervention on the teaching practices of teachers in the participating rural schools. The focus of this study was on teaching practices of teachers in these schools because they directly influence learners' performance. Professionally developing teachers improves their teaching practices, consequently, improving learners' performance (Darling-Hammond et al., 2017). This is possible because the teachers develop a deeper understanding of how they can support knowledge building, promote knowledge continuity, and emotionally engage learners in their lessons. These are all important aspects in enabling learning. Therefore, this study looked at how the teachers were teaching their learners

[1] Although this research is closely linked to the research project administering the intervention, it is independent and not part of the project. The role of this study was to determine the effectiveness of the intervention administered by the research project. The intervention was not administered by this study nor was the researcher of this study part of planning of its implementation.

before and after participating in the professional development intervention (sometimes referred to as intervention).

1.1.2. Teaching and learning in rural schools

There is no single accepted definition for the term rural. This is because definitions of this term are based on "different variables that may be used singly or in concert with one another, such as geography, economics, demography or the availability of resources" (Sayed & Gordon, 2016, p. 2). The lack of a single definition for the term rural has made it difficult to develop policies and programmes suited for the needs of schools in rural areas as well as efforts to improve the quality of education (DBE, 2017). This is a concern because Gardiner (2008) asserts that rural areas are spread across the nine provinces of South Africa even though the rural areas vary from each other with some provinces predominantly rural than others. Moletsane (2012) argues for the need to acknowledge the challenges rural communities face as well as the individual's agency within these spaces when defining the term rural. As such, this study defines rural or rurality as a "space which sustains human existence and development outside the jurisdiction of metropolitan/city/town authority" (Masinire et al., 2014, p. 148). This definition was adopted because it considers the diversity of rural contexts and the opportunities for development that may be offered by each rural area, thereby acknowledging rurality as a context and lived experiences.

In South Africa, most rural schools fall within quintile 1, 2 and 3, although a larger proportion falls under quintile 1 and 2. These schools are characterised by inadequate resources such as poor infrastructure and inadequate, or lack thereof, teaching and learning resources such as textbooks and science laboratories which are essential in aiding learners' understanding of taught knowledge (DBE, 2017; Mukeredzi, 2013). In this case, teachers become the main sources of information for the learners. The implication of teachers being the main source of information is that their teaching practices must be appropriate and effective such that they are able to promote knowledge continuity while supporting knowledge building and engaging learners. Otherwise, the status quo of education in rural schools being associated with education of poor quality, as van Dyk and White (2019) observed, will not change. Hence, it is necessary that these teachers are professionally developed, and the effectiveness of their professional development is frequently measured. This ensures that the professional development of teachers in these schools improves their teaching practices, learners' performance and the status quo of education offered in rural schools as necessary adjustments will be made to improve teaching practice. This study is expected to provide better insight on how the professional development intervention model could be improved upon. The findings of this study will assist in improving the rural teachers' professional development model.

A major challenge in rural schools is that it is "difficult to recruit, retain and develop qualified teachers in a rural setting due to distances of schools from towns, poor infrastructure and limited service delivery" (DBE, 2017, p.18). Mukeredzi (2013) outlines that qualified and experienced teachers leave their posts vacant in rural schools due to many factors including "geographical isolation, socio-economic conditions, cultural differences and the dominant discourse of deficiency that conceptualizes teaching in rural schools as inferior and undesirable" (p. 86). Mukeredzi (2013) adds that these posts are often filled by teachers who are either professionally unqualified or underqualified, teaching a subject and/or level of study they are not qualified to teach.

A teacher who did not specialise in the subject and/or level of study he or she teaches is said to be teaching out of field (Ingersoll, 1999) and is referred to as an off-field teacher in this study. Ingersoll (1999) argues that these teachers are less effective at promoting intellectual engagement and enthusiasm in learners. This is because the academic credentials and professional titles of teachers have a substantial impact on the cognitive achievements of their learners (Zheng et al., 2023). The ineffectiveness of off-field teachers in promoting intellectual engagement and enthusiasm implies that these teachers are unable to make links between ideas as they are teaching learners to aid and enhance their understanding. It is for this reason that Ingersoll (2001) argues that teaching out of field renders highly qualified teachers unqualified. Hence, learners taught by unqualified teachers are likely to perform poorly as compared to learners taught by qualified teachers. As such, the quality of education offered in these schools is usually poor (van Dyk & White, 2019). This study acknowledges that qualified teachers may also experience challenges in promoting intellectual engagement.

Redding and Henry (2019) add that rural schools are not only characterised by off-field teachers, they are also spaces in which many novice teachers often teach. For the purposes of this study, novice teachers were defined as teachers with less than five years of teaching experience (Caspersen & Raaen, 2014). Du Plessis et al. (2015) add that novice teachers are often given subjects or assigned levels of study they are not quilified to teach. However, a qualified teacher who is asked to take on a teaching task at a level for which he has not been trained (e.g. Math teacher asked to teach Physical Sciences), is regarded as teaching out of field. Out of field teaching is common in rural areas mainly because of the shortage of teachers (Masinire, 2015). It is for this reason that Rice (2010) considers rural schools to be double disadvantaged as they have higher proportions of inexperienced and ineffective teachers.

In order to address the abovementioned challenges, a professional development intervention was introduced to teachers in the rural schools within a circuit of Mpumalanga province. The aim of the intervention was to improve the teaching practices of novice, and out-field teachers, by helping them learn the content knowledge of their teaching subjects. It also aimed to assist them in learning how to teach the subject such that connections between ideas are made to engage learners in the lesson and enhance their understanding. Although the intentions of the intervention were to benefit the teachers, the effectiveness of the intervention had to be determined to ensure that it addresses the concerns of novice and off-field teachers with regards to their teaching practices. Therefore, the aim of this study was to provide such scrutiny to the intervention by determining its effectiveness on the teaching practices of these teachers. The results of this study will be used to inform and improve the intervention strategies, thereby enhancing the experiences of novice and off-field teachers participating in the intervention.

1.1.3. Teaching Physical Sciences in rural schools

Physical Sciences is a subject offered in most South African secondary schools comprising of two components, Chemistry and Physics. Ncube (2014) asserts that in some countries in the Southern African Development Community (SADC), such as Tanzania, Zambia and Zimbabwe, Chemistry and Physics are offered as standalone subjects from which learners can choose to either do one of the components or both. Zulu (2018) argues that the combination of Physics and Chemistry in the

South African Physical Sciences curriculum disadvantages many learners. He adds that this is because many learners may be competent and interested in one of the components, resulting in more effort being put in the component of interest while neglecting the other component (Zulu, 2018). Zulu's argument may be extended to teachers, particularly in rural schools where one teacher may be assigned to teach Grade 10 to 12 learners due to a shortage of teachers (Masinire, 2015). In such a school, the challenges of underperformance may be exacerbated by the teachers' preference or competence in one of the components of the Physical Sciences subject. For example, if the teacher is not comfortable with one of the components, they may not effectively teach that component, and that can result in poor performance in the subject. Hence, the need for professional development of teachers to improve their competence in teaching both components of Physical Sciences.

Physical Sciences is significant "for the country's economic growth and the social wellbeing of its people" (DBE, 2011, p. 8). However, due to the very small number of teachers graduating in getaway subjects, such as Physical Sciences, each year, as reported by the Centre for Development and Enterprise, CDE (2011), coupled with the observed difficulty to recruit and retain teachers in rural schools (DBE, 2017), this subject is likely to be taught by novice and off-field teachers in rural schools. Masinire (2015) reports that rural schools remain unattractive to qualified teachers. As a result, qualified teachers are mostly taken up by urban and township schools. Even when rural schools have managed to recruit novice and off-field teachers, research shows that these teachers are not given adequate support (Ingersoll & Strong, 2011; Ntsoane, 2017; Redding & Henry, 2019; See et al., 2020; Toropova et al., 2021).

In South Africa, the DBE has structures in place meant to provide support to teachers. For example, there are subject advisors within each education district office in a province. Education districts (or simply districts) are "geographical areas within a province that has been demarcated by the MEC *[Member of the Cabinet]* for education as the first level of administration and sub-division within a PED *[Provincial Education Department]*" (DBE, 2017, p. 4). They form a "link between Provincial Education Departments (PEDs), their respective education institutions and the public" (DBE, 2013, p. 4). Their duty is to provide all learners with access to quality education (DBE, 2013). A subject advisor is a "specialist office-based educator in a district office or circuit office whose function is to facilitate curriculum implementation and improve the environment and process of learning and teaching by visiting schools, consulting with and advising school principals and teachers on curriculum matters" (DBE, 2013, p. 11). Their roles include visiting schools to provide support to teachers, and principals, about what to teach and how to teach it. These visits are meant to help teachers to improve their teaching practices and the academic performance of their learners.

The Physical Sciences curriculum consists of six knowledge areas, (1) Matter and Materials; (2) Chemical Systems; (3) Chemical Change; (4) Mechanics; (5) Waves, Sound and Light; and (6) Electricity and Magnetism (DBE, 2011). With these six knowledge areas to be taught yearly, a subject advisor would be expected to visit each school at least six times a year. However, the Human Resource Development Council, HRDC (2014, p. 6) reported that "most of the subject advisors found it impossible to visit all the schools once in a year and possibly 30% or more of the schools were not visited at all". Stephen (2018) asserts that this is because of district sizes and the number of available subject advisors per district not corresponding with the nature of support required by each school. According to Stephen (2018), subject advisors are understaffed, particularly in districts that are responsible for many schools, resulting in some schools not being visited at all, if not once per year. This entails that the support teachers are receiving from the DBE in South Africa is insufficient, particularly for novice and off-field teachers. Novice and off-field teachers need additional support that would help them improve their teaching practices and the quality of education offered to their learners. However, such support must be examined to ensure that it benefits the teachers. Hence, the aim of this study was to determine the effectiveness of the support provided by the intervention to novice and off-field teachers in rural schools.

1.1.4. Impact of COVID-19 on teaching and learning in rural schools

In March 2020, the South African president declared the country to be under the state of disaster due to the Corona Virus, COVID-19, pandemic. With the country under the state of disaster, there were restrictions on movement to reduce and control the rapid spread of the pandemic. This introduced drastic changes in the country's education system. For example, schools had to adopt a rotational schedule to continue with teaching and learning. This approach meant that the number of learners per class had to be reduced, with some learners coming on a set day per week while others remained in their homes. This approach was favourable to schools experiencing learner overcrowding as teachers got to teach fewer learners per class, enabling the possibility of learners obtaining individual attention from their teachers during lessons. However, it also meant that the curriculum content had to be trimmed with some topics left out as the amount of time required to teach each topic was extended due to the rotational classes.

Furthermore, teachers with comorbidities could not continue with their teaching duties. Schools had to find substitute teachers without comorbidities to take over these teachers' posts. In some cases, the already employed teachers without comorbidities had to share the teaching load of those with comorbidities, thereby, teaching multiple grades and subjects (Pillay, 2021). While this affected the countrywide, schools in rural areas were extremely disadvantaged because of their current status quo of experiencing teacher shortages (Ogbonnaya & Awuah, 2019) and being unattractive to qualified teachers (Masinire, 2015).

Due to the challenges introduced by the emergence of COVID-19 in the education system, the need for professional development intervention to assist teachers with their teaching was exacerbated. This is because some of the substitute teachers were novices with no prior teaching experience while others were teaching off-field, thereby needing support in teaching their learners. While the need for professional development intervention was apparent, the restrictions to movement posed in South Africa to curb the spread of the corona virus prohibited face-to-face workshops. Thus, online professional development interventions comprising online workshops became popular. To provide the much-needed support to teachers in the rural schools of Mpumalanga, a research project administered an intervention comprising both online and face-to-face workshops, although face-to-face workshops were quite few, known as 'blended professional development intervention.'

Online workshops offered during the blended professional development intervention required teachers to have technological equipment, such as tablets and laptops, and access to internet to enable them to participate in the workshops. Marongwe and Garidzirai (2021) posit that there is a consensus in research that learning online, which includes online workshops, negatively affects the poorest members of the society because of limited access to technology and the internet..

Assuming that everyone has access to technonology, perpetuates the existing lack of equity, thus widening the gap between the pooerest and well-off members of the society. Furthermore, it hinders access to essential resources, including participation in professional development opportunities. While the teachers who participated in the intervention cannot be catergorised as the poorest members of society, the environments they were working in are disadvantaged, bearing the aftermath of the aparthied legacy as represented by the lack of essential teaching and learning resources (Mukeredzi,2013;DBE, 2017). As such, it vitally important to determine the effectiveness of the provided blended professional development intervention from different perspectives, particularly the teachers' point of view.

1.2. RESEARCH PROBLEM

There is a growing interest in research regarding the inadequate support, or lack thereof, provided by districts and DBE to teachers (Ingersoll & Strong, 2011; Ntsoane, 2017; Redding & Henry, 2019). This interest has led to the development of professional development interventions to support teachers. However, literature shows that there more focus on the professional development of teachers in general than the professional development of novice and off-field teachers (Darling-Hammond et al., 2017; Desimone & Garet, 2015; Patton et al., 2015; Powell & Bodur, 2019). Even the professional development interventions provided by the DBE tend to combine all teachers in the field and use a one-size-fits-all approach. This approach does not provide the required professional development to novice and off-field teachers as they have 'special' needs, different from those of other teachers. Therefore, there is need for extensive research on the professional development of novice and off-field teachers, particularly in rural schools. As indicated by Nkambule et al. (2011) and Zulu (2018), not much research has been done on rural schools.

Considering the role that the professional development of teachers can play in teaching, it is important to note of the fact that professional development interventions tend not to achieve their intended objectives (Kraft et al., 2018). This is evident in most of the studies that have been conducted where professional development interventions failed to change teaching practices and improve learners' academic achievement (Kraft et al., 2018). This is a concern and a shortfall of most interventions since professional development of teachers is assumed to be the best means to change the teaching practices of teachers leading to an improvement in the achievement of learners (Darling-Hammond et al., 2017). This entails that professional development interventions must be evaluated while underway to determine how their intended objectives were met, allowing the opportunity to make necessary changes in time. This study aims to provide such insight to the intervention and intends to address the identified gaps in research by examining the effectiveness of the intervention on the teaching of novice and off-field teachers in rural schools within the Mpumalanga province.

1.3. RESEARCH RATIONALE

Section 1.1. above has shown that schools in rural areas are facing a variety of challenges. These challenges have been exacerbated by the employment of novice teachers without the necessary support they need in place. Research has shown that novice teachers experience ‘transfer shock’, a “changeover period caused by the move from a familiar setting to one that is less familiar” (Caspersen & Raaen, 2014, p. 189). Caspersen and Raaen (2014) explain that during the transfer shock period, novice teachers experience stress, burnout, poor academic performance of their learners at times and, attrition. Ntsoane (2017) adds that this is due to experienced challenges in managing time, classroom, diverse learners, disciplining learners and managing conflicts with parents. This is most challenging for novice teachers in rural schools because they may not have mentors who will induct them into the profession and assist them with the transition since there is a shortage of teachers in these schools (Masinire, 2015; Ogbonnaya & Awuah, 2019).

The Personnel Administrative Measures (PAM) outlines that the members of the school management team (SMT), which includes subjects’ heads and the principal and deputy principal, are responsible for inducting novice teachers into the profession. This involves providing and co-ordinating guidance on “(1) the latest ideas on approaches to the subject, method, techniques, evaluation, aids, etc. in their field, and effectively conveying these to the staff members concerned (2) on syllabi, schemes of work, homework, practical work, remedial work (3) to inexperienced staff members (3) on the educational welfare of learners in the department” (DBE, 2016, p. 36). However, research by Ntsoane (2017) reveals that the members of the SMT are not equipped to provide such support. As such, novice teachers are left with two options which are to ‘swim or sink’ on their own.

Some of these novice teachers are recruited to teach subjects they are not qualified to teach (Du Plessis et al., 2015). This challenge is possible in getaway subjects such as Physical Sciences because the CDE (2011) reported that Higher Education Institutions (HEIs) produce a small number of teachers qualified to teach this subject yearly. Du Plessis et al. (2014) show that while novice teachers may be recruited to teach off-field, they do not receive the necessary support because principals claim that out of field teaching is a temporal appointment, as such, it is not worth investing in these teachers. There is no further research in this area that disproves or approves this claim by principals, particularly in rural schools. However, during the temporal appointment period, the learners taught by these teachers are disadvantaged. This is because these teachers lack the required subject content knowledge which, according to Magnusson et al. (1999), is the fundamental knowledge for teaching. Lack of content knowledge impedes the teacher from making effective connections between ideas to enable learning. It also hinders the teachers from effectively engaging the learners, meaning that it results into poor teaching practices. Therefore, novice and off-field teachers in rural schools need professional development support.

In some rural schools in the Mpumalanga province, the larger study piloted a professional development intervention as a means of support to novice and off-field teachers. The intervention was also implemented as a strategy to improve the quality of teaching and learning in the Physical Sciences subject, developing a model of support that may be used to professionally develop teachers in the future. Professional development has the potential to improve teaching practices and learner performance (Darling-Hammond et al., 2017). This province has been selected because it has a higher proportion of schools under quintile 1, 2 and 3 (see Mpumalanga school master list data: DBE, 2019), it is the only province without schools that have had a 100% pass rate in the past five year (see Figure 1), and experiences poor learner performance in Physical Sciences as shown in Table 1 below.

Table 1 below shows that there is a modest improvement in the number of learners taking Physical Sciences from 2019 to 2022. While this is plausible, it is important to note that the quality of passes, where learners achieve 50% and above, remains worryingly low, with an average of 25.6% from 2018 to 2022. In contrast, the percentage of learners achieving 30% and above from 2018 to 2022 remains high, at an average of 42.9%, and 42.9% for those learners achieving 40% and above. These results show that the quality of teaching is not improving with time as the percentage of quality passes remains low. This is a concern and raises a need for a well-organized professional development intervention for teachers in this province, particularly in rural schools, which can assist in improving the quality of teaching and consequently, learner performance in Physical Sciences.

Table 1: Mpumalanga learner performance in Physical Sciences from 2018-2022 *(Extracted from the National Senior Certificate Examination Report* DBE (2020, 2023b)*)*

Year	Total number of learners who wrote the final Physical Sciences paper	Physical Sciences pass rate at 30% and above	Physical Sciences pass rate at 40% and above	Physical Sciences pass rate at 50% and above
2018	20 387	70.2	44.1	25.8
2019	19 679	70.9	48.2	30.0
2020	21 794	60.0	37.9	22.9
2021	25 471	61.5	38.5	22.6
2022	25 763	68.1	45.6	26.7
Average	22 619	66.1	42.9	25.6

However, research shows that professional development interventions are not always successful in their endeavours (Kraft et al., 2018). This study intends to prevent such a trend with the intervention in Mpumalanga by examining its impact on the teaching practices of the targeted teachers while it is at its pilot stage. This study understands that change in teaching practice does not occur overnight. However, examining the intervention at its pilot stage will ensure that any challenges experienced by the teachers in their respective classrooms are addressed in due time, thus, improving the quality of teaching as well as the education offered to learners. Hence, this study needed to be conducted to ensure that the quality of teaching is indeed improved.

1.4. PURPOSE OF THIS STUDY

The purpose of this study was to determine the effectiveness of the professional development intervention offered to novice teachers on their teaching practice. This research study focused on the professional development experiences of novice teachers only. In this study, novice teachers were defined as those teachers with not more than five years teaching experience in the subject and level for which they were qualified to teach. This included those teachers who were qualified to teach the Physical Sciences as well as those who were assigned to teach Physical Sciences although it was not their subject of specialisation – a good example, would be Mathematics teachers who are appointed to teach Physical Sciences. The focus of this study was on these novice teachers with unique backgrounds, e.g. some teaching out of field, because of their need for additional support in teaching the subject. This study focuses on the effectiveness of the intervention on teaching practices because this aspect theoretically translates into improved learner performance, an end-product of improved teaching (Darling-Hammond et al., 2017). Therefore, the aim of this study was to address the following research question:

How effective was the blended professional development intervention in improving the teaching practices of novice Physical Sciences teachers in rural schools of Mpumalanga province?

To answer the research question above, the following sub-questions were addressed:

1. What are the teaching and learning needs of novice Physical Sciences teachers in the rural schools of Mpumalanga province?
2. What are the views of the novice Physical Sciences teachers about the effectiveness of the blended professional development intervention workshops?
3. In what ways have the teaching practices of Physical Sciences novice teachers changed after participating in a blended professional development intervention?

4. How were the identified teaching and learning needs of novice Physical Sciences teachers in the rural schools of Mpumalanga addressed by the blended professional development intervention?

1.5. SIGNIFICANCE OF THE STUDY

This study provides the intervention with an insight into its effectiveness in promoting change in the teaching of Physical Sciences. The insight provided by this study will benefit the teachers as necessary adjustments will be made by the intervention to ensure that it addresses their needs. Improving the teaching practices of the teachers will benefit the learners. Thus, this study is beneficial to the intervention, its participants, and the learners.

The findings of this study will also contribute to knowledge regarding the professional development of novice and off-field teachers, particularly those in rural schools as this is where this study was conducted. It is also contributing to research in rural schools. According to as Nkambule et al. (2011) and Zulu (2018) there relatively little research that has been done in South Africa on rural schools. Moreover, this study contributes to knowledge on blended professional development interventions which in this study was necessitated by the emergence of the COVID-19 pandemic, particularly in rural schools with varying needs.

1.6. SUMMARY OF THE CHAPTER

This chapter has provided a background of the study by outlining challenges faced by the South African education system. This included a discussion on how the classification of schools into quintiles has been insufficient for schools in rural areas. This is followed by a further discussion of how this has advanced poor learner performance in getaway subjects such as Physical Sciences. With this background, the chapter identified gaps in the literature regarding the professional development of teachers. This chapter also outlined the rationale for conducting the study, its purpose, research questions and significance. This chapter has provided an overview of the intervention. The next chapter will provide a review of the literature related to this study.

1.7. STRUCTURE OF THE DISSERTATION

This dissertation consists of eleven chapters. The first chapter provides the background of the study. It also outlines the aims of the study and the reasons for conducting this study. This chapter also provides the significance of this study for both literature or the research community and the participants who were involved in this study.

The second chapter provides a review of the literature related to this study. This involves an examination of research that has been conducted on the professional development of novice and off-field teachers. The third chapter outlines the conceptual framework that guided this study. The fourth chapter provides a detailed description of the professional development intervention offered to the teachers in the rural schools of Mpumalanga province.. The fifth chapter outlines the design of this study. It outlines the approach this study followed, and methods used to collect and analyse data. The fifth chapter briefly discusses the ethical issues that were taken into consideration when executing this study.

The sixth chapter provides a detailed description of the processes followed in analysing the collected data. It also reports the considerations made in enhancing reliability and validity of the findings. The seventh chapter reports and discuss the findings of this study relating to the first research question, while the eighth, ninth and tenth chapters report and discuss the findings of this study relating to the second, third and fourth research questions, respectively. The last chapter concludes the study; reports recommendations and outlines the study limitations.

CHAPTER TWO: LITERATURE REVIEW

2.1. INTRODUCTION

The purpose of this study is to examine the effectiveness of a blended professional development intervention in rural schools of Mpumalanga on the teaching practices of novice Physical Sciences teachers. Professional development is a "long-term process that includes regular opportunities and experiences planned systematically to promote growth and development in the profession" (Villegas-Reimers, 2003, p. 12). Professional development of teachers is about enhancing "the quality of students' learning by improving the quality of teaching through constant review and assessment of teachers' instructional approaches, identifying the effective teaching approaches and capitalising on them for the benefit of the effective teaching approaches and capitalising on them for the benefit of the learners" (Luneta, 2012, p. 362). Hence, Darling-Hammond et al. (2017) contend that professionally developing teachers promotes more learning opportunities for learners. In other words, constantly developing teachers professionally has the potential to improve their effectiveness.

In South Africa, subject advisors are considered experts in their respective subjects and phase of specialisation, thus, they are expected to provide continuous professional development to teachers during their visits to schools. This is because subject advisors are supposed to work closely with teachers, observing them as they perform their duties and provide them with constructive feedback regarding their interaction with the learners and content knowledge taught (Stephen, 2018). Stephen (2018) adds that subject advisors are also supposed to help teachers to use the provided feedback to improve their effectiveness, enabling professional growth. However, Galane (2016) contends that teachers see subject advisors as inspectors whose role is to detect faults in what the teachers are doing. As a result, teachers tend to reject the support subject advisors are supposed to give them and ignore any advice they receive from the subject advisor. This is advanced by the top-down approach subject advisors use which, according to Dilotsothle et al. (2001), is about making teachers comply with the regulations of the DBE rather than working cooperatively with teachers.

Subject advisors' use of a top-down approach is influenced by their view of teachers. Bantwini and King-McKenzie (2011) found that subject advisers see teachers as being resistant to change because they pretend to have learnt during workshops but displays no evidence of learning in their teaching when the implementation of what was taught in the workshops is measured. According to Bantwini and King-McKenzie (2011), teachers are not resistant to change as they found that subject advisors, representing the DBE, did not follow-up on teachers to help them implement what they learnt in the workshops, and since teachers are not able to implement it, they are considered to be resistant to change. These contesting views indicate that professional development is born out of different purposes, thereby necessitating different models of professional development. These models and their effectiveness are discussed below.

2.2. MODELS OF PROFESSIONAL DEVELOPMENT

Kennedy (2005) has identified and classified models of professional development based on their ability to support professional autonomy and transformative practice. These models are shown in Table 2 below.

Table 2: Spectrum of professional development models (Kennedy, 2005, p. 248)

Models of professional development	**Purpose of the model**
The training model The award-bearing model The deficit model The cascade model	Transmission
The standards-based model The coaching/mentoring model The community of practice model	Transitional
The action-research model The transformative model	Transformative

Increasing capacity for professional autonomy

Table 2 above shows that professional development can be transmissive, transitional, and transformative. Transmissive professional development is about passing knowledge from the teacher to the learner (Lee et al., 2023). In teacher professional development, the teacher is the facilitator who may be an official from DBE, and the learner is the teacher. According to Lee et al. (2023), transmissive professional development is teacher centred as it comprises of the facilitators imparting knowledge while teachers adopt a passive role. It is therefore, about promoting replication and compliance (Fraser et al., 2007). The training, award-bearing, deficit, and cascading models are transmissive in nature; hence they fall under the transmission category where teachers have the least professional autonomy, as shown in Table 2 above. Professional autonomy basically describes the teachers' level of involvement in each model with regards to the choices of what is to be learned for their own professional development.

The training model regards professional development as an opportunity for teachers to professionally development their skills to be able to remain competence even though they remain passive throughout the training. In South Africa, this model is similar to the top-down approach usually used by subject advisors. Dilotsothle et al. (2001) found this approach to be about enforcing compliance with the regulations of the DBE. Hence, it is often used to promote quality assurance, with coherence and standardisation being the focus of the training (Kennedy, 2005). The nature of this professional development model presents a limited view of teachers as its aims overshadow the professional development needs of the teachers as well as the need for them to be proactive during training (Kennedy, 2005). Lee et al. (2023) argue that professional development can shape practice only if the needs of the teachers are taken into consideration. Furthermore, Mushayikwa (2009) argues that hands-on engagement with teachers is more fruitful than training teachers. Thus, teachers need to be allowed to take an active role in the workshops rather than a passive role. The training model cannot shape teaching practice as it is not informed by the needs of the teachers, and it promotes passive engagement.

Although the training model is considered effective in introducing new knowledge, it fails to facilitate the implementation of this knowledge in practice (Kennedy, 2005). This is evident in the findings of Bantwini and King-McKenzie (2011), where they found that subject advisers did not support teachers in implementing the new knowledge obtained from the training through follow-up visits to their respective schools. Such lack of support has also been identified as a challenge in Ghana, thereby impeding teacher development (Salifu et al., 2024). In South Africa, the failure by teachers to implement the new knowledge in their practice is considered to be resistance to change by the subject advisors (Bantwini & King-McKenzie, 2011). Subject advisors' lack of visits to provide support to teacher has been reported by the HRDC. The HRDC, 2014, p. 6) noted that "most of the subject advisors found it impossible to visit all the schools once in a year and possibly 30% or more of the schools were not visited at all". This lack of support to teachers to implement the new knowledge, coupled with the passive role of the teachers during the training, makes it inevitable for this model to fail to aid change in practice. In rural schools, such failure is exacerbated by the distance between the schools (Mukeredzi, 2013), thereby contributing greatly to the observed poor learner performance. The lack of support has devastating effects in rural schools, as reported by Mukeredzi (2013), they comprise novice and off-field teachers who need support in teaching their allocated subjects.

The award-bearing model is award-driven and is dependent on the completion of a validated programme (Kennedy, 2005). These programmes are usually validated by universities to ensure quality assurance while also exercising control over the focus of the professional development received by teachers (Kennedy, 2005). The exercise of control over the focus of professional development received by the teachers entail that the model is not based on the identified needs and interests of the teachers. This suggests that the model is not mindful of the individual teachers' context, particularly those from rural schools. As such, teachers are less likely to find them useful and relevant in addressing their teaching practice challenges. Thus, this model shares similar traits with the training model, in that they are both do not take into consideration the needs and interests of the teachers.

The deficit model of professional development emanates from the identified weaknesses of individual teachers (Kennedy, 2005). According to Kennedy (2005), this model does not extend responsibility to other stakeholders, e.g. poor management, it attributes responsibility to individual teachers only. Kennedy (2005) adds that this model facilitates a baseline measure of competence, which is used to inform the content of professional development. While the need for baseline measure of competence may be justified, the lack of consideration of other responsible stakeholders may render the professional development ineffective. This is evident in the Bantwini and King-McKenzie's (2011) findings where subject advisors blame teachers for failing to implement the knowledge gained during the professional development intervention while they take no blame for their failure to provide the teachers with required support. Based on the similar challenge faced in Ghana, Salifu et al. (2024) proposed that workshop organisers must follow-up with the teachers to determine any gaps in skill development and provide the necessary support to address such gaps. Such support will be advantageous to teachers, especially those in rural areas with diverse teaching and learning challenges.

The cascade model of professional development involves individual teachers attending interventions, then coming back to share what has been learned with fellow teachers (Kennedy, 2005). While this model is cost effective, teachers tend to neglect attitudes and values and give preference to knowledge and skills when they share what they have learned with their fellow teachers (Kennedy, 2005). Since teachers tend to neglect the attitudes and values, the recipients of this information do not get to know the importance of the shared knowledge and skills, thereby increasing the likelihood of poor implementation. This is possible because teachers also tend to not share the context in which the knowledge and skills were gained from and/or used (Kennedy, 2005).

Transformative professional development is about providing support to teachers, enabling them to contribute to education and shape practice (Kennedy, 2005). According to Lee et al. (2023, p. 377), this approach to professional development "should engender critical analytical consideration of knowledge, concepts and theory and assimilate these into everyday professional contexts". As such, it combines action-research and the transformative model, as shown in Table 2 above.

The action-research model involves teachers as researchers who research their own practice with the aim of improving it (Kennedy, 2005). The quality of the action taken by the teachers is defined by their "understanding of the situation, as well as the practice within the situation" (Kennedy, 2005, p. 245). This model of professional development enables teachers to engage in research activities that are informed by their own needs and interests. As such, it limits their dependency on research produced externally, thereby allowing them to take ownership of their own learning (Kennedy, 2005). The action-research model requires teachers to have a strong sense of their own capabilities, enabling them to engage in self-directed professional development.

Self-directed professional development refers to a teacher's initiative to engage in professional development arising from the teacher's will to learn (Van Eekelen et al., 2006). Mushayikwa and Lubben (2009) consider self-directed professional development as a breakthrough for teachers in rural schools. This study concurs with this argument because such self-development has the capacity to improve their teacher efficacy where they will learn how to support learners' knowledge building, promote knowledge continuity in their teaching subjects and promote active engagement during lessons. However, such self-development is possible whenever the teachers are willing to associate themselves with the subject, particularly off-field teachers. Teachers who do not identify with the subject they are teaching have low professional efficacy which affects their classroom efficacy. Hence, it is important that the needs of each teacher, from a professional and classroom perspective, are considered during a professional development intervention as they have the potential to improve teacher efficacy, consequently, positively affecting teaching practice and learner performance.

The transformative model of professional development is not clearly defined; however, it acknowledges the variety of conditions necessary for transformational practice (Kennedy, 2005). This model effectively combines a range of models with a genuine understanding of power dynamics to support a transformative agenda (Kennedy, 2005). The combination of a range of models should also be centred around an understanding of the needs of the teachers. This is because professional development can only be transformative if the needs of the teachers are taken into consideration (Lee et al., 2023). Although this model has the potential to influence teaching practice considering that it harnesses the strengths of each model, however, the necessary conditions to be met with regards to this model have not been outlined, except for consideration of teachers' needs. Thus, indicating lack of evidence that the effective combination of range of models will lead to improved teaching practices. This, therefore, contributes to the observed gap between research and practice (Korhonen et al., 2024).

A translational professional development approach has the capacity to support the activities of either transmissive or transformative professional development (Kennedy, 2005). In other words, it can facilitate the dissemination of information using the transmission models while promoting a change in teaching practice using the transformative models. Table 2 above shows that this approach offers an increase in professional autonomy, compared to the transmissive professional development where teachers are encouraged to take ownership of their learning with necessary support in place. As such, it comprises of the standards-based; coaching/mentoring and community of practice models.

The standards-based model is informed by the behaviourist view of learning, which emphasises the individual teacher's abilities (Kennedy, 2005). As such, it enables teachers to engage in conversations based on the provided standards about their practice (Kennedy, 2005). However, this model is criticised mainly because of the standards imposed on the teachers. According to Kennedy (2005), the standards imposed on the teachers are considered to be disrespectful as (1) they provide clearly established guidelines for the amount of responsibility teachers should take for their own professional development; and (2) they compel them to be dependent for everything, including evaluating their own teaching abilities. This model undermines the self-efficacy of teachers. This is particularly the case for those teachers in rural schools where self-directed professional development, which relies heavily on their self-efficacy, is considered to be the only breakthrough for teachers in rural schools (Mushayikwa & Lubben, 2009).

The coaching/mentoring model places emphasis on one-on-one interactions in promoting professional development (Kennedy, 2005). Although both coaching and mentoring share common traits, they are slightly different. For example, coaching is focused on skills development while mentoring provides room for counselling, enabling professional friendship (Kennedy, 2005). Coaching/mentoring may take place within a school amongst colleagues, for example, between a novice and experienced teacher, where the experienced teacher may be inducting the novice teacher into the system (Kennedy, 2005).

Given the crucial role played by the mentor/coach in professionally developing the mentee, Kennedy (2005) contends that it is important for the mentor/coach to have well-developed interpersonal communication skills, be willing to support the mentee, and must be trained on the support to be provided. Similarly, Mukeredzi (2013) underscores the need for a focused and comprehensive mentor training for teachers taking on the role of a mentor in school-based professional development. According to Mukeredzi (2013), this mentor training ensures that mentees receive the required support while promoting professional growth for the mentors. It is the view of this study that certificates of competence must be issued at the end of the training or professional development initiative. Such certificates serve as formal recognition of a mentor's skills, knowledge, and ability to effectively guide and support others. Such recognition can serve as a motivation for mentors to engage deeply in their roles, leading to better outcomes for mentees.

The community of practice model is similar to the coaching/mentoring model, except that it involves more than two people (Kennedy, 2005). This model finds its roots from the social theory of learning where learning is perceived to be a result of interaction between community members. Through this interaction, members of the community gain knowledge and experience, thereby serving as a potent hub for the generation of new knowledge (Kennedy, 2005). In South Africa, this interaction often occurs during cluster meetings. Jeta and Mokhele (2014) reported that teachers typically use the clusters to identify and address their deficits in content and pedagogical content knowledge as well as to improve their understanding of the curriculum frameworks. In addition, the teachers exchanged ideas regarding the pedagogy and general classroom practice issues they were facing (Jita & Mokhele, 2014).

Kennedy (2005) posits that power dynamics may positively and/or negatively affect the activities of the community of practice. As such, all members of the community of practice must have some degree of influence over the agenda and must not perceive their engagement in the community is as a form of accountability and/or performance management (Kennedy, 2005). If the members of the community of practice perceive the setting as a form accountability, their interactions are restricted, resulting in limited exchanges amongst members. Therefore, a culture of trust and openness must be fostered in a community of practice, ensuring effective leadership and governance, and maintaining a clear and shared vision for the community.

The discussion above shows that for professional development to shape teaching practice, it must strategically utilise a range of models. The selection of the models should be informed by the purpose of professional development and needs of the teachers. Regardless of the models being adopted, the discussion above reveals that there are additional important features that must be taken into consideration for professional development to achieve its objectives. These features are sustainability, duration, collective participation, content, active learning, and coherence. According to Garet et al. (2001), these features are more significant than the types of professional development. This is because a sustained and intensive professional development that is focused on content knowledge and is aligned with the everyday activities of the teacher at school while promoting active participation is more impactful than a short professional development programme (Garet et al., 2001).

2.3. FEATURES OF TEACHERS' PROFESSIONAL DEVELOPMENT

There is consensus among researchers that for professional development interventions to be successful, they need to consider the features outlined in Figure 2 below. According to Desimone (2009), these core features are "associated with changes in knowledge, practice and, to a lesser extent, changes in student achievement and are described as "holding promise" for increasing student achievement" (p. 183).

Figure 2 below shows that teachers' professional development needs to be content focused to change the way they teach. According to Desimone (2009) and Patton et al. (2015), this involves a focus on the content knowledge, and how learners conceptualise that knowledge. Content knowledge is the "knowledge of the subject and its organizing structures" (Ball et al., 2008, p. 2). According to Magnusson et al. (1999), it is challenging for teachers to learn strategies that will enable them to effectively respond to the learning needs of their learners without content knowledge. This knowledge is referred to as subject content knowledge (SCK) because it is subject-specific. SCK informs teachers' pedagogical content knowledge (PCK) which is about organising SCK to make it accessible to learners (Shulman, 1986). However, for PCK to be developed, SCK needs to be in place. Thus, teachers' professional development must focus on improving teachers' SCK and PCK. According to Jita and Ndlalane (2009) professional development that targets these knowledge areas can change teachers' classroom practices. Since this feature is fundamental in teaching practice, this study examined how the teachers promoted knowledge building in their lessons. The purpose of this was to determine any changes in the way teachers engaged learners before and after participating in the intervention, thereby determining the effectiveness of the intervention in improving their teaching practice. This study, however, acknowledges that learner engagement is influenced by various factors which may impede and/or enhance their performance. This includes, for example, motivation and access to resources.

Figure 2: Features of professional development

Figure 2 above shows that teachers' professional development should be coherent, meaning that it should be based on the needs and interests of the teachers and should be grounded in the improvement of learners' achievement (Kaino et al., 2015). Bayar (2014) adds that professional development activities should also be aligned to the needs and interests of learners as well as the DBE goals, and the goals of the schools. This feature is important since teachers engage in professional development to improve the achievement of their learners (Letloenyane & Jita, 2020). As such, teachers might not see the significance of professional development if it not based on their needs and interests or focusing on how to improve their learners' achievement. This feature is at the core of this study as two research questions aim to understand the teaching and learning needs of the teachers and how those needs were addressed by the intervention.

Figure 2 above identifies active participation as another feature necessary in teachers' professional development. According to Patton et al. (2015) and Desimone (2009), this feature demands that teachers be treated as active learners, meaning that teachers should be allowed to participate in their professional development which includes being observed while teaching and given constructive feedback. This feature was lacking in the professional development interventions offered by DBE to teachers in South Africa according to Bantwini and King-McKenzie (2011). In the DBE workshops, teachers would remain passive throughout the sessions and be expected to implement what was said in the workshops when teaching (Bantwini & King-McKenzie, 2011). Although this feature is now evident in some teacher workshops from DBE, it is still lacking as it does not support reflection and action. Mushayikwa (2009) argues that hands-on engagement with teachers is more fruitful than training teachers. Thus, teachers need to be allowed to take critical and active roles in the workshops rather than a passive role.

In addition, Patton et al. (2015) identified that professional development must acknowledge that learning is a social process, thus showing consistency with Vygotsky's view of learning as outlined in the socio-cultural theory of learning. Treating learning as a social process allows teachers to voice out their thinking as they go through professional development. This involves taking part in discussions that involve the content they need to teach to their learners and how to teach it. It further involves being context specific by finding out teachers' needs, probably through the use of video stimulated recall interviews approach, whereby teachers are video recorded while in action and using the video to stimulate recall during an interview. Such involvement enables internalisation of the social activities, that is, the discussion between teachers and mentors in the intervention. Internalisation is the process of transforming a social activity into a psychological activity (Wertsch, 1985). This internalisation is observable in the way the teacher conducts their lessons. In this study, this was sought by seeking evidence of change, or lack thereof, in the way they support knowledge building in their lessons.

The fourth feature necessary in teachers' professional development is the encouragement of collaboration. According to Desimone (2009), this may involve teachers in the same schools or across schools forming professional learning communities (PLCs) and/or communities of practice where they will professionally develop one another. An example of this core feature is the cluster meetings common in South Africa where teachers from different schools come together to address administrative and pedagogical concerns (Jita & Ndlalane, 2009). Research has shown that by attending these cluster meetings, teachers have shown improvement in their SCK and PCK (Jita & Mokhele, 2014). De Clercq and Phiri (2013) contend that cluster meetings dissolve teachers' isolation.

Figure 2 outlines that teachers' professional development should be of longer duration. According to Kaino et al. (2015), an extended period is necessary for teachers to digest what they have learnt. This is in line with the definition of professional development given by Villegas-Reimers (2003), that it is a long-term process and cannot happen over a one-day training. Thus, it is only sensible to allow teachers sufficient time and support to implement what they have learnt in their teaching. Although sufficient time should be provided for teachers to engage in their own professional development, Desimone (2009) explains that the exact term duration has not been clearly identified. However, research seem to encourage "activities that are spread over a semester (or intense summer institutes with follow-up during the semester) and include 20 hours or more of contact time" (Desimone, 2009, p. 184).

Figure 2 indicates that professional development should be continuous and sustained. This core feature is important because teachers should be able to use the skills, they have learnt during the intervention to continuously develop themselves, enabling sustainability. Mushayikwa (2009) contends that professional development is possible to sustain if it is learned in a context similar to their working environments, meaning that it should be conducted in schools. According to Mushayikwa (2009), this may be accomplished by practically demonstrating the knowledge taught during professional development interventions. In this way, teachers will be able to see the feasibility of implementing what they have learned in professional development interventions. It is for this reason that this study observed teachers in their natural settings to determine the effectiveness of the intervention in improving their teaching practices.

In addition to the above listed features, Darling-Hammond et al. (2017) urge that practice and feedback are important features in the success of professional development. Reflection and feedback enable teachers to "think about, receive input on, and make changes to their practice" (Darling-Hammond et al., 2017, P. 24). As such, time should be reserved for teachers to reflect on their practices and be given constructive feedback to shape their teaching practice. Darling-Hammond et al. (2017) report that feedback and reflection often involved sharing both positive and constructive comments on real examples of teaching, such as lesson plans, demonstration lessons, or instructional videos in effective professional development initiatives. According to Darling-Hammond et al. (2017), these activities typically occur during coaching/mentoring sessions that are led by an expert or in group workshops, with feedback sometimes, exchanged among teachers.

The above observations reveal that reserving time for reflection and feedback will serve as a great opportunity for teachers in rural schools to elaborate on their learning experience and reveal areas of development. This will address any gaps that are not covered by workshops, thereby, enhancing the teachers' professional development experience. Reflection and feedback also emphasise the importance of coaching/mentoring in shaping teaching practice (Darling-Hammond et al., 2017). In other words, coaching/mentoring is one of the models that offer teachers an opportunity to reflect and be given constructive feedback.

Although the above components have been deemed effective in promoting effectiveness in professional development, there seem to be no mention of the importance of facilitators' expertise in professional development activities. Facilitators are practitioners responsible for the design and execution of teacher professional development activities, including teacher workshops. This suggests that professional development facilitators are under-researched, and their importance is undermined (Perry & Booth, 2024). This is a concern and a gap in knowledge as facilitators are expected to have high levels of expertise to be able to contribute meaningfully to the professional development of teachers. It is, therefore, the view of this study that expert facilitators be included as one of the components that contribute to effective professional development. However, more research is required to determine the constituent of the facilitators' expertise this may include their years of experience in the field, level of education, education specialisation, and learner performance track record, amongst others.

The features identified and discussed above are deemed essential in the delivery of a successful professional development intervention and improving teaching practice. However, this study did not examine these features to ascertain how they have contributed to the success, or lack thereof, of the intervention in improving the teaching practices of the teachers. In this study, the effectiveness of the intervention in improving the teaching practices of the teachers was determined by investigating how the identified teaching and learning needs of the teachers were addressed. It was also determined by positive changes in the way teachers promoted knowledge building in their lessons after participating in the intervention, as well as their view of the professional development intervention.

2.4. MODES OF PROFESSIONAL DEVELOPMENT

Professional development can be provided using different modes, some being online and others being face-to-face. Professional development that takes place in a physical setting, enabling face-to-face interaction, is known as face-to-face/traditional professional development (Powell & Bodur, 2019). The features of professional development presented by Figure 2 above were derived from literature of this mode of professional development (see Darling-Hammond et al., 2017; Desimone & Garet, 2015; Patton et al., 2015). According to Powell and Bodur (2019), access to this mode of teacher professional development is hindered by geographical, financial, and time limitations. This mode of professional development is costly as it requires venue bookings and transportation, particularly if it is not school based with schools located at far away distance from one another. As such, attendance might not be great. Hence, Toman and Maag (2024) suggest that provision of resources must be made available to improve attendance. Due to the constraints posed by this mode of professional development, the online mode is often preferred (Powell & Bodur, 2019).

Professional development that takes place online, often called online professional development, uses available technologies to promote teachers' professional development (Powell & Bodur, 2019). This mode of professional development emerged due to challenges posed by time and geographical constraints which limited access to opportunities for professional development (Powell & Bodur, 2019). However, through the integration of technology in professional development, these challenges can be addressed. For example, online professional development is flexible and cost-effective as it can synchronous, asynchronous and/or blended, thus enabling self-paced learning (Powell & Bodur, 2019). Belland et al. (2015) warns that providing too much flexibility in asynchronous online professional development may reduce the participation of teachers in online activities.

Powell and Bodur (2019) argue that online professional development does not guarantee quality professional development if technology is only utilised as a tool to deliver workshops without adequate design. They add that the tenets outlined in Figure 3 below should be addressed when designing professional development for teachers online.

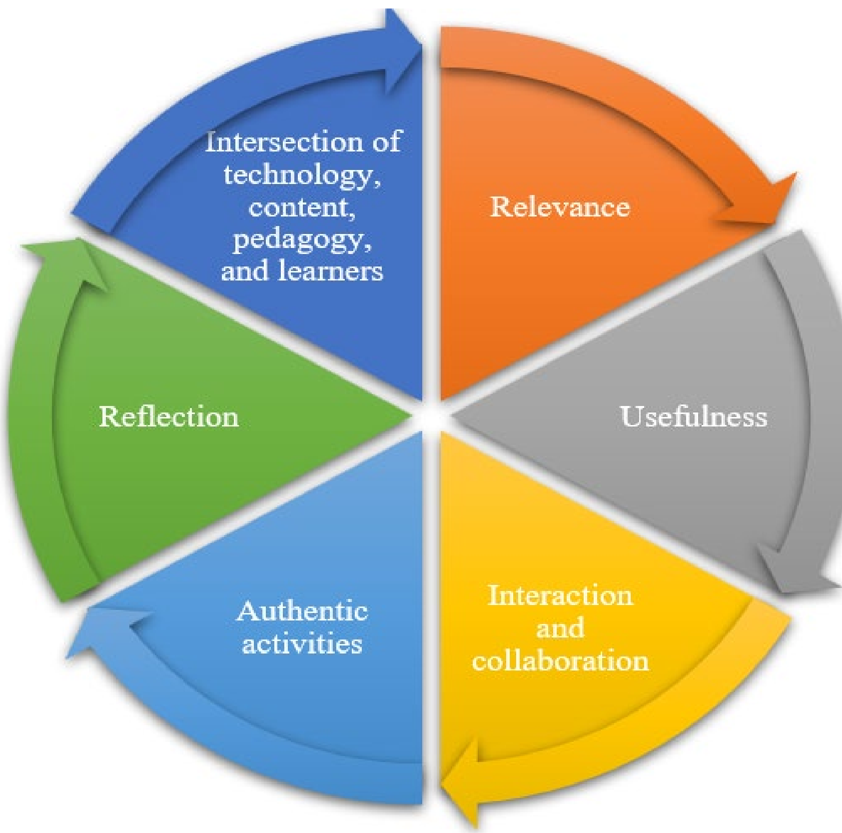


Figure 3: Key tenets for Designing online teacher professional development *(extracted from* Powell and Bodur, 2019).

Firstly, Figure 3 shows that online professional development should be relevant to the teachers. This aspect was also highlighted by Bragg et al. (2021) in their synthesis of studies that systematically examined online professional development initiatives for teachers. Furthermore, it was suggested by Toman and Maag (2024) that providing relevant content during professional development initiatives has the potential to improve attendance. According to Powell and Bodur (2019), relevance entails that online teacher professional development must be informed by the teaching and learning needs of the teachers. Secondly, Figure 3 shows that online professional development should be useful to the teachers. This means that it should assist the teachers in meeting their teaching and learning needs in the classroom and beyond (Powell & Bodur, 2019).

Thirdly, Figure 3 shows that online professional development should encourage interaction and collaboration. According to Powell and Bodur (2019), this tenet entails that online professional development should provide opportunities for teachers to engage in different types of interactions that will enable learning. Fourthly, Figure 3 shows that online professional development should provide opportunities for teachers to engage in authentic activities. Authentic activities serve as a bridge between what has been learned and the realities of the classroom, thereby helping teachers to apply newly acquired knowledge to their teaching practice in a real classroom setting (Powell & Bodur, 2019). Bragg et al. (2021) presented a similar concept to authentic tasks which is practical learning activities. This shows that such activities are significant and should not be undermined during professional development initiatives.

The fifth tenet in designing online teacher professional development, as shown in Figure 3 above, is reflection. Reflection was also found to be fundamental in the synthesis presented by Bragg et al. (2021). This suggests that opportunities for teachers to reflect should be provided in an online teacher professional development. According to Powell and Bodur (2019), reflection enables teachers to relate the newly acquired knowledge to the realities of their own classrooms. Prestridge and Tondeur (2015) also identified reflection as a significant feature that supports effective engagement in online teachers' professional development. Philipsen et al. (2019) indicates that feedback is one of the significant methods that can foster teacher reflection in online professional development. In other words, feedback should be utilised to probe reflection.

Lastly, Figure 3 shows that the intersection of technology, content, pedagogy, and learners should be considered when designing an online teacher professional development. This tenant highlights the importance of transforming content knowledge, instead of transferring it into a technological platform. Therefore, to enable a connection between teachers (who are learners during professional development) and technology, one must use their knowledge of online pedagogies to transform the content of professional development (Powell & Bodur, 2019). This last tenet distinguishes online professional development from traditional professional development as Figure 3 shows that the other tenets overlap with those in Figure 2. This indicates that the tenets identified in Figure 2 are applicable in online professional development.

While these tenets are promising, they cannot guarantee the success of any online professional development programme. This is because many studies are experiencing a challenge in replicating this mode of professional different contexts and obtaining the same results (Lay et al., 2020). One of the factors that may constrain the effectiveness of an online development in professional development, regardless of context, is teachers' attitude towards the use of technology (Dille & Røkenes, 2021). Negative teacher attitudes may emanate from their lack of required competency and experience in using the technology for their professional development, thereby affecting their level of engagement in online professional development activities (Belland et al., 2015; Tsiotakis & Jimoyiannis, 2016). As a result, teachers must be trained on how to use technology for their professional development. Belland et al. (2015) add that this negative attitude may also be the result of teachers not being familiar with interacting asynchronously with fellow teachers.

Since online professional development may be synchronous, that is, occurring in real time, participants tend to turn off their cameras. While this action is said to be reducing bandwidth interference and distractions, Gherheș et al. (2021) argues that this is an issue to be investigated, particularly in terms of attention and level of engagement in class activities. This is because there is no evidence showing that participants are paying attention and engaging in a synchronous activity when their cameras are turned off (Gherheș et al., 2021). Although Gherheș et al. (2021) study focused on students' behaviours, its findings and arguments are relatable to that of teachers in their online professional development.

Hunt-Barron et al. (2015) investigated challenges faced by teachers in using technological tools to improve professional development in rural areas. Firstly, they found that teachers felt overburdened and could not add more tasks to accomplish on their plate, such as posting a reflection online. These findings correspond with those of Tsiotakis and Jimoyiannis (2016) who found that teachers' lack of personal time influenced their participation in online activities. This is a concern because the lack of time can be a direct result of increased workload due to shortage of teachers in schools around rural areas. Moreover, research shows that even though schools sometimes manage to recruit teachers, they are unable to retain them due to lack of support and conducive working environment (See et al., 2020; Toropova et al., 2021). In other words, there is a strong likelihood that these teachers will not remain in these schools for long.

Secondly, Hunt-Barron et al. (2015) found that teachers have a desire for privacy, hence they find it troublesome to post on a platform that many people have access to, either sharing ideas or seeking assistance. Lastly, they found that teachers frequently experienced challenges with network coverage which caused them to lose internet connection, consequently, hindering their access to professional development.

Mukuna and Aloka (2020) found that lack of electricity, poor network coverage, and cost of data were some of the factors that constrained online learning in rural areas in South Africa. Although Mukuna and Aloka (2020) study focused on challenges experienced by teachers in promoting online learning for their learners, their findings are relatable to the challenges faced by teachers in rural areas when participating in an online professional development. While lack of electricity and poor network coverage are issues beyond the control of any professional development programme, the issue of cost of data can be addressed. Research shows that lack of data is a barrier that negatively affects the level of engagement in any online activity, regardless of the context (Campbell, 2019). This entails that teachers should be provided with adequate resources, such as data bundles and technological learning devices, to enable access to online opportunities of professional development (Mukuna & Aloka, 2020).

To overcome the challenges of each of the modes of professional development discussed above, the strengths of the two modes of professional development should be harnessed to generate a blended professional development (Palvia et al., 2018). A blended professional development is a mode of professional development that combines effective elements of online and traditional professional development to promote change in teaching practice. Following on Palvia et al. (2018) suggestion, this study has harnessed the effective features of professional development in traditional mode, as shown in Figure 2, and online mode, as indicated in Figure 3, to derive a framework outlining components of blended professional development. When implemented accordingly, these tenets have the potential to promote a change in teaching practice, thereby making the blended professional development intervention effective.

Figure 4 shows that blended professional development must be content focused, with greater focus on developing SCK and PCK. These are features that Desimone (2009); Patton et al. (2015) and Darling-Hammond et al. (2017) have identified as crucial in professional development that aims to shape teaching practice. Figure 4 shows that blended professional development needs to be relevant and useful to the teachers, thereby promoting coherence. This means that this professional development must be informed by the teaching and learning needs of the teachers and should aid teachers in addressing these needs (Powell & Bodur, 2019). Figure 4 shows that blended professional development must promote active engagement using authentic tasks and encourage reflection. The use of authentic tasks and reflection have been identified by Powell and Bodur (2019) as essential in promoting active engagement with content.

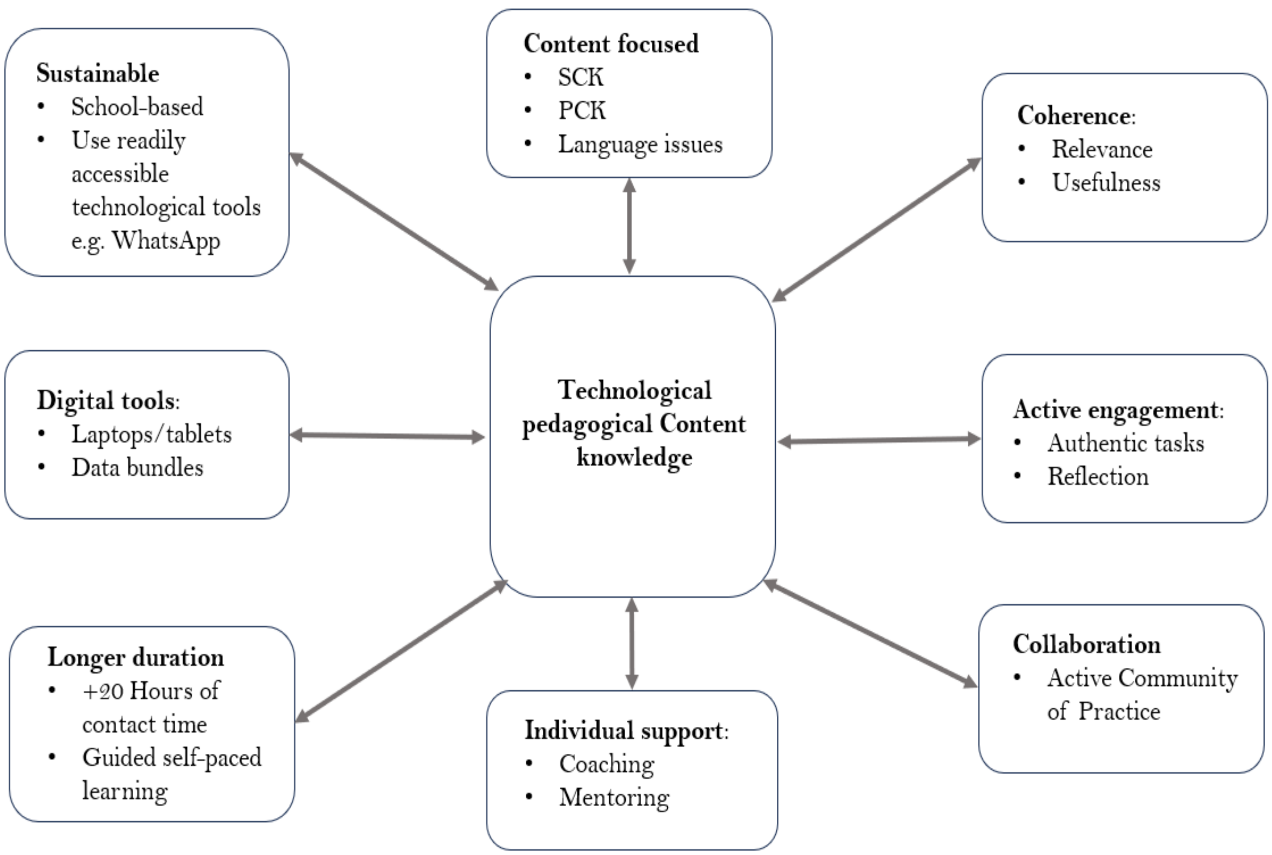


Figure 4: Effective blended professional development framework.

Blended professional development must encourage collaboration, as shown in Figure 4, by encouraging the formation of communities of practice. For communities of practice to be effective, they should create leadership roles for their members, allow members to decide what and how they want to learn, develop principles that will facilitate the functioning of the communities, and should be supported by the organisers of professional development (Trust & Horrocks, 2019). Furthermore, they should allow members to facilitate some learning activities, use technology to extend support and build a sense of community (Trust & Horrocks, 2019). The purpose of the community of practice should be co-developed with its members and must be revisited and re-developed in line with the teachers' changing needs and interests (Trust & Horrocks, 2019).

Figure 4 shows that blended professional development must make provisions for individual support. This aspect came from the challenge raised by Hunt-Barron et al. (2015) of teachers needing privacy, thereby opting to directly engage with anyone who can assist them instead of posting publicly. This aspect can be addressed through the introduction of the coaching and/or mentoring models of professional development. Through these models, teachers can obtain constructive feedback that they can use to improve their teaching practices.

Figure 4 shows that blended professional development must also be of long duration with at least 20 hours of contact time (Desimone, 2009). It must also make provisions for self-paced learning. Guided self-paced learning is important because research shows that teachers do not have much time on their hands (Hunt-Barron et al., 2015; Tsiotakis & Jimoyiannis, 2016). Through guided self-paced, teachers can reduce the pressure posed by time while also ensuring that they remain proactive during the blended professional development process.

Figure 4 also shows that blended professional development initiatives must provide teachers with digital tools. These digital tools include, amongst others, laptops/tablets, and data bundles. These tools can enable access to online opportunities of professional development, such as attending online workshops. This component of the framework was necessitated by the consensus in research that learning online, which includes online workshops, negatively affect the poorest members of the socienty because access to technology and internet is deemed to be available to everyone (Marongwe & Garidzirai, 2021). Similarly,Mukuna and Aloka (2020) found that the lack of these resources hindered access to opportunities of learning online.

To ensure sustainability, Figure 4 shows that blended professional development must be conducted in schools, where teachers are employed. Mushayikwa (2009) argued that professional development is possible to sustain if it is learned in a context similar to the teachers' working environments. Figure 4 shows that sustainability can be promoted by utilising readily accessible technological tools such as WhatsApp. These technological tools should be used to extend face-to-face engagements, ensuring that teachers can interact with one another anytime and anywhere. This diminishes isolation of teachers in rural areas.

At the centre of this blended professional development framework is technological pedagogical content knowledge, TPCK/TPACK, which Powell and Bodur (2019) recognise as the intersection of technology, content, pedagogy, and learners. TPCK refers to the teacher's knowledge and skills on how to efficiently use technology in teaching and learning (Kulaksız & Karaca, 2023). It defines "teachers' subject-specific skills for technology-enhanced lessons such as teaching methods, strategies, and use of tools" (Kulaksız & Karaca, 2023, p. 3003). TPACK is the integration of the SCK with technological knowledge (TK) and PCK (Niess, 2005). Designers/organisers of blended professional development intervention must have adequate TPACK to be able to efficiently use technology to enable access to professional development and the shaping teaching practice. In other words, this aspect signifies the importance of facilitators and their expertise in the success of professional development (Perry &Booth,2024).

Niess et al. (2009) has developed four components that must be addressed in integrating technology in teaching. Although these components were developed for teaching, they are applicable in designing blended professional development. The first component is a consideration of the purpose of integrating technology in teaching. In teachers' professional development, this includes an understanding of the challenges teachers experience in accessing professional development, as well as their teaching and learning needs. The second component is an understanding of how learners use technology to learn, think about, and understand SCK. The third component is familiarity with the curriculum and resources that use technology to enhance the teaching and learning of a subject. Lastly, is the knowledge of methods and representations for teaching and learning a subject using technology. It is the view of this study that a thoughtful consideration of these components, in relation to the other tenets in Figure 4, will enhance the effectiveness of the blended professional development.

2.5. PROFESSIONAL DEVELOPMENT OF TEACHERS IN RURAL SCHOOLS

In South Africa, cluster meetings are the most common professional development initiative for in-service teachers. Cluster meetings serve as professional learning communities established by the department of education to serve as collaborative learning communities for teachers (Feldman, 2020). Ajani and Govender (2018), note that cluster meetings are effective in shaping teaching practice due to the assistance received from peers. Jita and Ndlalane (2009) argue that the effectiveness of this professional development initiative lies in the interactions among teachers, trust and identity. According to Jita and Ndlalane (2009), teachers feel empowered and develop a shared sense of collegiality, ultimately influencing their commitment. While Jita and Ndlalane (2009) argue that clusters develop teachers' SCK and PCK, Glover et al. (2016) note that cluster meetings tend to focus largely on the analysis of assessment results. Bertram and Mxenge (2023) say that the activities of cluster meetings in South Africa addresses two purposes, (1) to improve learners' assessment results, and (2) monitor teachers' curriculum coverage and assessment practices. These contrasting views show that the structure of cluster meetings is influenced by many factors which research has yet to delve into. However, a balanced combination of SCK, PCK, and assessment practices has the potential to provide comprehensive professional development, making the professional development initiative relevant and useful.

A major drawback of cluster meetings, as a professional development initiative, is its lack of strategies to follow-up and support teachers beyond the cluster meeting (Ajani & Govender, 2018). Without follow-ups, teachers may not be able to effectively integrate the knowledge and skills acquired. They also do not receive constructive feedback which could assist them refine and improve their practices over time. These can result into teachers being demotivated, particularly because the support they receive is limited to their meetings. Establishing strategies for ongoing support and feedback after cluster meetings can help teachers integrate new skills and knowledge effectively, leading to continuous improvement in teaching practices.

Another common professional development initiative in South Africa is teacher workshops. These workshops are usually facilitated by external experts. According to Kahts-Kramer and Wood (2023), these workshops are not sustainable in that professional development activities seize with the end of the professional development initiative. Hence, Admiraal et al. (2021) suggested that professional development initiatives should be embedded in the organisation and culture of the school for it to be sustainable. However, such initiatives are challenging to achieve in rural schools due to the shortage of qualified teachers for getaway subjects such as Physical Sciences.. Rural schools rely on workshops for professional development. However, resources must be made available to ensure that teacher professional development is continuous even after the expert has left. The sustainability aspect in Figure 4 requires further exploration to assist in addressing this issue.

The last common professional development initiative in South Africa is subject advisor visits. These visits are mandatory and, according to Stephen and Motlhabane (2020), are meant to support the teachers develop SCK and PCK. However, the HRDC (2014) reports that subject advisors often find it impossible to visit every school even once a year, resulting in possibly 30% or more of the schools not being visited at all. Stephen (2018) reports that the discrepancy between the size of districts and the number of available subject advisers per district does not align with the support needed by each school. Specifically, Stephen (2018) points out that subject advisors are often understaffed, especially in districts overseeing numerous schools, leading to some schools not being visited at all or only once a year.

Furthermore, Stephen and Motlhabane (2020) have revealed that the support provided by subject advisors to teachers is significantly influenced by their university qualifications though some of them may be out-of-field. Stephen and Motlhabane (2020) explain that some subject advisors are out-of-field and/or are not competent in all areas of the SCK. This is a concern because they are expected to be experts that can provide substantial support to the teachers in school. Effective teaching requires a combination of SCK and PCK. Thus, these subject advisors are not in a position to provide the required support to the teachers. In other words, the subject advisor visits do not always serve as an opportunity for teachers to be professionally developed. Therefore, it is essential that subject advisors are adequately trained and possess the necessary qualifications in both SCK and PCK to provide adequate and effective support to teachers.

Although these professional development initiatives exist, they have many challenges that require intervention from researchers to improve their effectiveness. This is important because they are cost effective and do not usually involve local people, except for workshops. Thus, they can be useful in providing continuous professional development to teachers in all contexts, including rural areas. This study will provide insight into how these professional development initiatives can be advanced to ensure that they are effective and grounded on the teaching and learning needs of the teachers.

2.6. SUMMARY OF THE CHAPTER

This study acknowledges that there are different reasons for engaging teachers in professional development. Different models of professional development and their purposes were discussed in this chapter. This was followed by a discussion of features of effective teacher professional development and modes of professional development. The discussion of the modes of professional development resulted into the development of a framework for blended professional development. The framework combined key tenets of traditional and online professional development. The framework also acknowledges the significant role of TPACK, where technology is utilised to enhance the effectiveness of professional development.

This chapter has discussed some professional development initiatives that are common in South Africa, exploring their affordances and challenges. The next chapter discusses the effect of teacher efficacy in professional development. It further scrutinises the pedagogical link-making (PLM) framework and legitimation code theory (LCT) as a conceptual framework used to understand teaching practice in the classroom.

CHAPTER THREE: CONCEPTUAL FRAMEWORK

3.1. INTRODUCTION

In the previous chapter, relevant literature related to the study was discussed. This includes a discussion of the features of professional development in a face-to-face intervention, online professional development interventions, and blended professional development intervention. This chapter draws concepts from different frameworks to develop a conceptual framework for this study. A conceptual framework is a "network, or "a plane," of interlinked concepts that together provide a comprehensive understanding of a phenomenon or phenomena" (Jabareen, 2009, p. 51). The conceptual framework of this study is undergirded by the concept of self-efficacy in order to understand the effect of teachers' efficacy in professional development.

Self-efficacy is "people's beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives" (Bandura, 1994, p. 1). It is a set of beliefs in one's capability to influence circumstances to attain the desired outcome. According to Bandura (1994), self-efficacy governs how people motivate themselves, feel, think, and behave. Bandura (1994) adds that an individual may hold different levels of self-efficacy concerning each action. For example, a person may hold high self-efficacy in educational outcomes and low self-efficacy in sports outcomes. Shohani et al. (2015) contend that people with high self-efficacy do not shy away from challenging tasks, they think of them as challenges they need to master and that increases commitment to the task. As such, they recover quickly from failure as it is considered a temporal setback attributed to the inadequate effort (Bandura, 1994). According to Bandura (1994), such people meet their desired outcome, and their outlook of life reduces proneness to suffering from stress and depression. On the other hand, Shohani et al. (2015) assert that people with low self-efficacy tend to question their capabilities and lack motivation, resulting in inadequate effort being put into the set outcome or activity, consequently, increasing their likelihood to suffer from depression and stress.

The conceptual framework of this study integrates concepts from the Pedagogical Link Making framework as well as the Legitimation Code Theory to explore and understand the teaching and learning that took place in the classrooms of the three novice Physical Sciences teachers. The Pedagogical Link Making framework as well as the Legitimation Code Theory are discussed in detail in this chapter.

3.2. THE EFFECT OF TEACHER EFFICACY IN PROFESSIONAL DEVELOPMENT

Previous research has shown that that for professional development to be successful, certain features must be carefully considered (Darling-Hammond et al., 2017; Desimone, 2009; Patton et al., 2015; Powell & Bodur, 2019). However, Mushayikwa and Lubben (2009) argue that the presence of these features does not guarantee that a professional development intervention will be successful. Bantwini and Diko (2011) reveal that teachers who lack the 'drive' for their teaching subjects neither reach out for assistance when they encounter challenges nor go an extra mile to deliver high-quality education to their learners. In rural schools, as observed by Bantwini and Diko (2011), this is partly caused by teaching out of field as well as the appointment of subject heads who do not have any science background, making it impossible for them to give constructive feedback to their teachers. Following Bandura (1994), what is being referred to as the 'drive' by Bantwini and Diko (2011), can be understood as self-efficacy.

As alluded to earlier, teachers' self-efficacy/teacher efficacy is defined as teachers' own set of beliefs about their capability to successfully perform tasks related to teaching (Mushayikwa & Lubben, 2009). According to Mushayikwa and Lubben (2009), teacher efficacy is influenced by their self-esteem, level of higher education, nature of teaching, collaboration, new knowledge, practical work, adaptation, and pass rate. Mushayikwa and Lubben (2009) further classify teacher efficacy into two groups, namely classroom efficacy and professional efficacy and these are illustrated in Figure 5 below.

Figure 5 below illustrates that professional efficacy, which is associated with the teachers' working environment, is influenced by professional networking, professional identity, and career development. Professional networking involves teachers associating themselves with professional learning communities (PLCs) leading to collaborative practice opportunities and individual's development (Mushayikwa & Lubben, 2009). A typical example of professional networking is the cluster meetings where, as reported by Jita and Mokhele (2014),teachers would use these meetings to address their deficiencies in SCK and PCK. This results in career development where teachers would engage in self-development to better themselves in their professions and stand a better chance of being promoted (Mushayikwa & Lubben, 2009). Consequently, their professional identity, which refers to their "values, attitudes, ethics and morals associated with being a teacher" (Mushayikwa & Lubben, 2009, p. 380) improves.

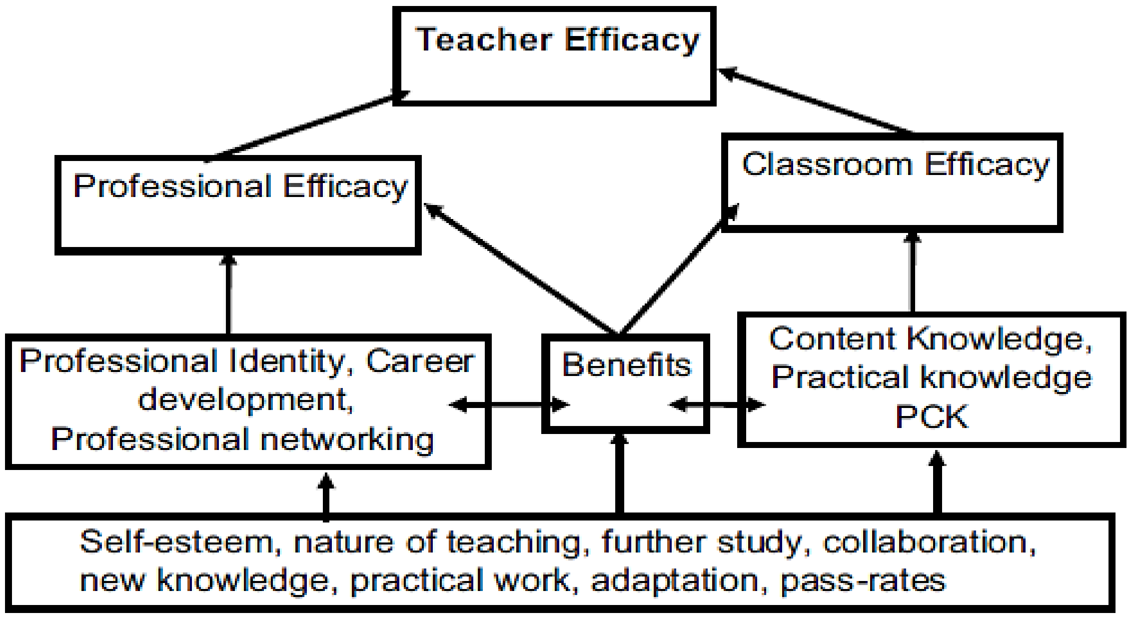


Figure 5: Thematic map of concerns leading towards self-directed professional (Mushayikwa & Lubben, 2009, p. 380)

In rural schools, it is difficult to establish professional networks that can be utilised to professionally develop teachers due to shortage of qualified teachers and long distances between schools (DBE, 2017). As such, teachers in rural schools are likely to have low professional efficacy. In off-field teachers, this may be perpetuated by the inability to identify with their teaching subjects, particularly if they believe that teaching out of field is a temporary post, that they will teach their subject of specialisation in the near future. Such a view negatively affects these teachers' involvement in any career development that may have to do with their teaching subject, thereby, affecting their professional efficacy. This is because Bandura (1994) outlined that individuals will professionally develop themselves on fields that are of interest to them including the fields they identify with, such as subjects that off-field teachers were trained and qualified to teach.

In a lesson and schooling environment, professional efficacy can be examined through (1) classroom management, (2) professional identity, and (3) professional integrity (Mushayikwa & Mushaikwa, 2023). Classroom management refers to a set of strategies used to create a conducive learning environment. Amongst other aspects, classroom management involves the effective use of time in a lesson, suitable pacing of the lesson, and techniques to maintain discipline (Mushayikwa & Mushaikwa, 2023). Research has showed that novice teachers often experience difficulties with this aspect of professional efficacy which includes challenges in managing time, classroom, diverse learners, disciplining learners and managing conflicts with parents (Ntsoane, 2017). Ntsoane (2017) reveal that these challenges are exacerbated by the lack of mentors to support and induct the novice teachers into the profession. These kinds of challenges in classroom management result in low professional efficacy among novice teachers.

In interpreting professional efficacy in terms of professional identity, one examines the values, attitudes, ethics, and morals associated with being a teacher (Mushayikwa & Lubben, 2009). In a lesson, it is observed as the teacher's attitude and enthusiasm towards learners and their teaching subject (Mushayikwa & Mushaikwa, 2023).

Research has shown that peoples' attitude influences their behaviour and performance (Ekperi et al., 2019; Ulug et al., 2011). Ulug et al. (2011) explain that a negative attitude leads to failure. Similarly, Ramohapi et al. (2015) observe that learners performed poorly on subjects to which they hold unfavourable attitudes. It is therefore important that teachers must portray a positive attitude towards their learners and subjects, by showing eagerness to teach the subject and enabling learner understanding, embrace learner differences and use various teaching and learning strategies to enable learning. Such an attitude is likely to evoke enthusiasm and engender a positive attitude among learners about the subject, resulting in improved performance. While it may be relatively easy for novice teachers who are qualified to teach the subject to portray a positive attitude and enthusiasm, it may be relatively challenging for off-field teachers. This is because off-field teachers have limited SCK which is likely to induce stress and burn out since they have to put an extra effort in comprehending the SCK and transforming it for learners to learn. As such, it may take a while for off-field teachers to develop their professional identities in their out-of-field subjects/phases.

Both professional identity and professional integrity demonstrate the teacher's ethical principles and attitudes, towards their teaching profession (Mushayikwa & Mushaikwa, 2023). Teachers with high professional integrity portray a sense of responsibility and commitment towards the performance of the learners in their teaching subjects. They must show commitment to adhere to ethical conduct at all times. Such ethical practice is fundamental not only in Physical Sciences teachers but to any other teaching subject. Zulu (2018) argues that learners in South Africa are often interested and competent in one component of Physical Sciences, thereby putting more effort in their component of choice than the other. This results in poor overall performance in the subject as each component has an equal weighting in the examination. Zulu's argument may be extended to teachers, especially in rural areas where, as reported by Mukeredzi (2013),the shortage of teachers is often addressed by the employment of novice teachers who are either qualified or unqualified to teach the subject. For example, when a teacher teaches only one component of Physical Sciences without putting any effort in the other component that they are less competent in, their conduct is unethical and compromises the performance of the learners. Thus, their professional efficacy is considered low and require professional development to improve their competency in both components of the subject.

Classroom efficacy is different from professional efficacy as it is related to the act of teaching and learning. According to Figure 5 above, classroom efficacy is influenced by the teachers' subject content knowledge (SCK) and pedagogical content knowledge (PCK) where teachers are knowledgeable about topics to be taught in a subject, how they overlap and make them accessible to learners. As shown in Figure 5 above, classroom efficacy is influenced by practical knowledge, which is the teachers' knowledge of teaching methods and general presentation. This entails that teachers with low classroom efficacy are likely to display a lack of SCK and PCK for their teaching subjects, resulting in the adoption of inactive teaching methods that impede active engagement with the learners and poor general presentation. Such an act is likely to be seen in off-field teachers who are unqualified in the subjects they are teaching. It may also be seen in novice teachers when teaching topics, they are uncomfortable with within their subject of specialisation. However, through professional development their classroom efficacy may be improved by improving their SCK and PCK.

According to Mushayikwa and Mushaikwa (2023), teachers' PCK and SCK, with regards to classroom efficacy, can be understood in terms of (1) comprehension; (2) content representation; (3) instructional selection and (4) adaptation of content in teaching. Comprehension refers to the teacher's understanding of content knowledge for the subject (SCK) (Mushayikwa & Mushaikwa, 2023). This involves an understanding of the subject concepts, how the concepts are linked from one topic to the next and how the subject is organised (Ball et al., 2008). It also involves an understanding of the language being used in the subject, how it can promote learning opportunities and/or serve as learning barrier (Ramohapi et al., 2015). It is about being able to identify technical terms from non-technical ones within the subject and topic. Technical terms refer to scholarly concepts that are specific to the subject (Oyoo, 2009). Non-technical terms refer to a scholarly terminology that is used in science classrooms as general yet sophisticated aiding the explanation of scientific or technical terms (Quílez, 2019). Non-technical terms "act as fundamental components of the reasoning processes necessary to construct, comprehend and use complex scientific ideas, which involves to employ and relate abstract concepts performing higher-order thinking" (Quílez, 2019, p. 128). When a teacher possesses a solid comprehension of the SCK, they are able to adequately represent the content to the learners since SCK informs PCK (Magnusson et al., 1999).

Content representation refers to the approach that the teacher uses to present and foster a deeper understanding of SCK. It involves identifying big ideas (ideas that unify interlinked ideas that learners must understand at the end of the topic/lesson) from each topic, use of analogies and examples from everyday life to provide explanations that enable a comprehensive understanding of SCK (Mushayikwa & Mushaikwa, 2023). The identified big ideas, provided explanations, selected analogies and examples require a teacher to have a solid comprehension of the SCK. Lack of solid SCK comprehension pose a challenge to teachers as they find it difficult to devise strategies that enable them to effectively respond to the learning needs of their learners (Magnusson et al., 1999).

Hence, it is of utmost importance for teachers to have a solid SCK comprehension to effectively represent the SCK and facilitate learning during a lesson.

Instructional selection refers to the choice of strategies used by the teacher to effectively teach and facilitate learning in the lesson (Mushayikwa & Mushaikwa, 2023). Some of the teaching and learning strategies that may be used by the teacher to present SCK include experiments; role playing; group work; and discussions. Instructional selection also involves the choice of teaching resources used to aid learning in a lesson (Mushayikwa & Mushaikwa, 2023). Research shows that availability of teaching and learning resources influences the choice of instruction adopted in a lesson and directly influences learner performance (Ramohapi et al., 2015). While lack of teaching and learning resources may affect all teachers, the effect may be severe in off-field teachers who are less competent in the subject. As such, they are likely to adopt teaching and learning strategies that are less effective at promoting intellectual engagement and enthusiasm in learners (Ingersoll, 1999). The same argument may be extended to novice teachers who are experiencing 'transfer shock' with little to no experience in teaching the subject.

Adaptation of content is about making the SCK accessible to the learners by considering their learning needs and level of understanding (Mushayikwa & Mushaikwa, 2023). In other words, it recognises and embraces the diversity in a classroom, where learners may have different learning abilities/styles and different conceptions about a phenomenon/topic. To cater for learner differences, Danso and Mushayikwa (2018) recommend that appropriate teaching and learning strategies be adopted to effectively enable learning. In a lesson, this would involve an understanding and identification of misconceptions and/or alternative conceptions learners may have on each topic, and concepts that they may find difficult and easy to understand – components of PCK (Shulman, 1986). Thereafter, the teacher may use this understanding to select various approaches to represent the SCK and engage the learners while capitalising on their learning abilities. In other words, the teacher must have a good understanding of their learners to be able to adapt SCK to their level and enable learning.

While professional efficacy and classroom efficacy may appear to be unrelated, Figure 5 above shows that they directly influence one another, entailing that low professional efficacy may lower classroom efficacy or vice versa. For example, a teacher who is experiencing difficulties with adapting the content to the needs and level of the learners is likely to have challenges with classroom management where the lesson pacing is usually poor. In the example above, adaptation of content is a classroom efficacy component that affects classroom management and the professional efficacy component. Therefore, during professional development, teachers must be developed on both aspects of teacher efficacy (professional and classroom efficacy).

See (2014) provides a typical example of the relationship between professional and classroom efficacy. See (2014) says that after engaging in professional development, most novice teachers displayed an increase in their PCK while others reported a decrease in their PCK. According to See (2014), novice teachers who reported a decrease in PCK lacked confidence after critically reflecting about what they can and cannot control when teaching. In terms of teacher efficacy, these novice teachers display low professional efficacy in terms of classroom management, which directly influenced their PCK, a significant component of classroom efficacy, as shown in Figure 5 above. According to Bandura (1994), these teachers are more likely to suffer from stress and depression. As a result, these teachers are less likely to engage in self-directed professional development, particularly in cases where opportunities to be professionally developed in their working environment are scarce.

In this study, teacher efficacy, in terms of both classroom and professional efficacy, is used to understand the teaching and learning needs of the teachers and how the identified needs have been addressed by the intervention. This framework was used to assess the effectiveness of the professional development intervention. Hence, an interpretivism paradigm was adopted to unearth the needs of these teachers as experienced in the rural schools. Chapter six provides a detailed explanation, with examples, of how teacher efficacy was used as an analytical framework to address the teaching and learning needs of the teachers, and how these were addressed by the intervention. A detailed discussion of these findings is presented in Chapters seven and ten.

3.3. THE PEDAGOGICAL LINK-MAKING FRAMEWORK

Scott et al. (2011) developed a pedagogical link-making framework that is foundational and fundamental in the teaching of science. Pedagogical link-making is "concerned with how teachers and students make connections between ideas in the ongoing meaning-making interactions of classroom teaching and learning" (Scott et al., 2011, p. 3). According to Scott et al. (2011), pedagogical link-making can be achieved in three ways, (1) promoting knowledge building, (2) promoting knowledge continuity, and (3) encouraging learners' engagement. Although all these components of pedagogical link-making are important in a lesson, this study focuses only on knowledge building. This is because knowledge building is the core of any teaching practice, tapping on the teachers' SCK and PCK. The different approaches that can be used to promote knowledge building are illustrated in Figure 6 below.

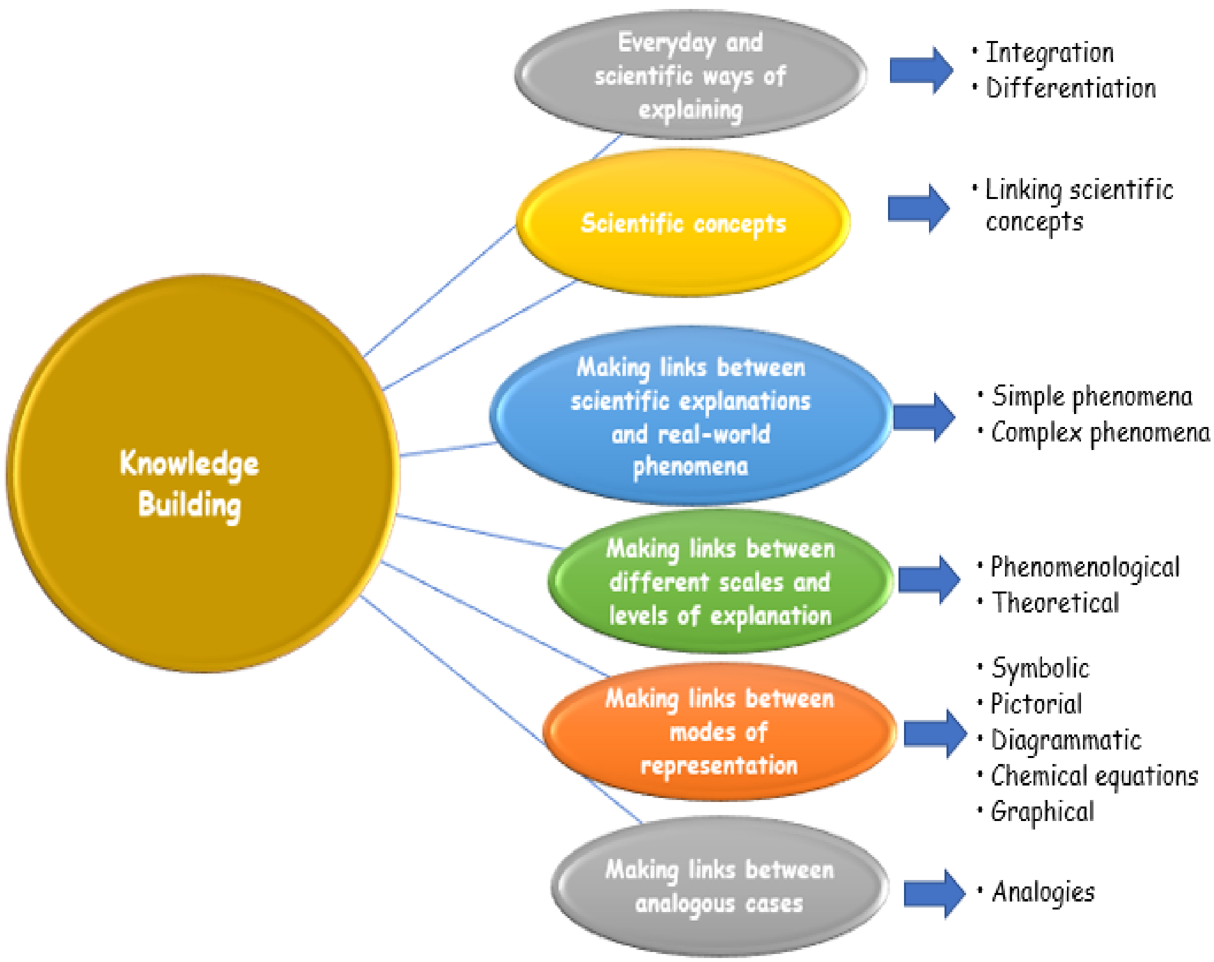


Figure 6: Approaches of promoting knowledge building – PLM *(adapted from* Scott et al. (2011)*)*

The first approach to supporting knowledge building, as identified by Scott et al. (2011), involves the use of everyday and scientific ways of explaining as illustrated in Figure 6above. This approach acknowledges that there might be an overlap between the meanings of concepts used in an everyday context and a scientific context. Thus, it involves identifying concepts used in everyday and scientific context with different and/or similar meanings. Oyoo (2009) call these concepts technical terms as they are specific to the science subject. Where the meanings of these concepts vary with each context, Scott et al. (2011) argue that teachers will have to explain what the concept *is* in scientific context and what *it is not* in the scientific context. This is different when the concept meanings are the same in both contexts. Furthermore, Scott et al. (2011) contend that the meanings need to be integrated, and link everyday views with scientific explanations. The idea of integration and differentiation shows that Scott et al. (2011) shares the same views as Oyoo (2009, 2012, 2016) who argues that language issues act as barriers to learning and must be addressed for effective engagement with content in science lessons.

While the first approach to supporting knowledge building may seem obvious, it may be difficult for teachers to accomplish it. For example, Hoadley (2007) and Sikoyo and Jacklin (2009) indicate that teachers in low quintile schools could not successfully integrate everyday knowledge with scientific explanations to aid learners' scientific knowledge building. Sikoyo and Jacklin (2009) note that teachers in these schools tended to use everyday knowledge as an alternative to scientific knowledge due to poor SCK and PCK. As a result, the quality of education received by learners in these schools is compromised. Therefore, if this approach is not well executed, it may cause knowledge fragments and poor learner performance. As part of evaluating the effectiveness of the intervention meant to professionally develop novice teachers, this approach was looked at. Any improvement and concerns in the teaching practices of these teachers were identified and will be used to improve the intervention.

Scott et al. (2011) add that scientific concepts should also be treated as an interlinked system where an understanding of each concept requires an understanding of other concepts, thus links between scientific concepts need to be made to ensure a systematic understanding. This is the second approach that has been identified to support knowledge building, as illustrated in Figure 6 above. The approach enables a deeper understanding of scientific concepts and denotes the teachers' understanding of their teaching SCK. Without the knowledge of SCK, teachers are unable to link scientific concepts and even use everyday knowledge to support scientific knowledge building.

Hence, this study also looked at how novice teachers link Physical Sciences concepts in their lessons as part of evaluating the effectiveness of the professional development intervention on their teaching practices.

The third approach to supporting knowledge building involves making links between scientific explanations and real-world phenomena, enabling a practical application of scientific explanations. According to Scott et al. (2011), this link requires an awareness of the learning demands related to various phenomena. A teacher may start from simple to complex phenomena. This is important in Physical Sciences because of the abstract nature of the concepts involved in this subject where learners might find it difficult to link the knowledge offered in the course with any phenomenon they encounter in their everyday lives. When this link is made, learners can understand the practicality and relevance of the subject and that has the potential to improve their interest in it. Thus, it is important that this link is made during the teaching of Physical Sciences. In this study, this approach was evaluated in the teaching practices of novice teachers as it is also essential in the teaching of Physical Sciences.

Making links between real-world phenomenon and scientific explanations may involve the use of different modes of representation, such as mathematical expressions; chemical equations; diagrams and graphs, as the fourth approach in supporting knowledge building. When these modes of representations are used, as argued by Scott et al. (2011),they should be linked to enable a sound understanding of the scientific explanations. In Physical Sciences, representations are often used to illustrate what is beyond the surface. Their use demands an in-depth understanding of the Physical Sciences content knowledge so that they can support knowledge building. Teachers' failure to effectively use representations in Physical Sciences causes poor understanding and poor learner performance.

The links may be at different scales/levels. According to Scott et al. (2011), the links may be at phenomenological or theoretical level. The phenomenological level looks at concrete and visible phenomena while the theoretical level involves phenomena that cannot be seen with the naked eye (Scott et al., 2011). Scott et al. (2011) further argue that the links between these levels of explanations should be made explicit as learners may be left at the phenomenological level, thus lacking an adequate understanding of the phenomenon at the theoretical level or vice versa. This link also demotes the teacher's understanding of SCK and those who lack such knowledge are not able to move between the phenomenological and theoretical levels effectively without leaving learners in between. Thus, the use of this approach was assessed in the teaching practices of novice teachers as it is essential in the learning and effective teaching of Physical Sciences.

The last approach is about making use of analogies to support learners' knowledge building. According to Scott et al. (2011), this approach is not essential in the teaching of science although it may be useful in aiding learners' knowledge building. However, an understanding of the five approaches discussed above is necessary when this approach is to be used. Such an understanding is significant because teachers with limited understanding may not be able to differentiate between scientific and everyday concepts; interlink scientific concepts; link real-world and scientific phenomena; use and link modes of representation and link phenomenological and theoretical levels of explanations. This study examines the use of this approach, as used by novice teachers as they were supporting knowledge building in Physical Sciences lessons.

The different approaches of promoting knowledge building outlined above are important in understanding the teaching practices of novice teachers. The connections that teachers make to enable learning in their lessons form part of their teaching practices and tap into their SCK and PCK. It is these connections that teachers make during their lessons that is of interest to this study as they were developed by the professional development intervention. As such, this knowledge building aspect of the PLM framework was used to determine the effectiveness of the professional development intervention on the teaching practices of novice teachers. However, this framework alone will not provide us with an understanding of how these teachers were shifting from one PLM approach to the next to promote knowledge building. Hence, this study uses the semantic dimension of the legitimation code theory to show the shift between the different PLM approaches as novice Physical Sciences teachers were promoting knowledge building. The use of the legitimation code theory along with the PLM framework provides a visual comparison of the teaching practice of the novice Physical Sciences teachers before and after participating in the blended professional development intervention.

3.4. THE LEGITIMATION CODE THEORY: THE SEMANTICS DIMENSION

Legitimation Code Theory (henceforth LCT) is a framework that builds its ideas from the work of Basil Bernstein and Pierre Bourdieu (Maton, 2011). LCT provides a tool in which teaching practice can be analysed and shaped (Maton & Howard, 2018). LCT consists of five dimensions, namely, Autonomy, Density, Specialization, Semantics, and Temporality. According to Maton and Howard (2018), "each dimension includes concepts for analysing a set of organizing principles underlying practices, dispositions and contexts as a particular species of legitimation code" (p. 5). Although all these dimensions are useful in analysing teaching practice, this study focuses on the semantic dimension. This is because the Semantic dimension enables researchers to analyse how teachers transform complex knowledge into simple forms and relate it to a context, making it accessible to learners. The Semantic dimension uses the organising principles of semantic gravity and semantic density as semantic codes (Maton & Howard, 2018).

Semantic gravity (SG) explores the extent in which meaning is related to a context (Maton, 2011). In such a case, the focus is on how a teacher brings abstract concepts closer to learners' everyday lives and/or real-world situations (Walton & Rusznyak, 2020). According to Walton and Rusznyak (2020), semantic gravity is context-bound, entailing that the conveyed meaning can be only understood better in a specific context, than when it is transferred to other contexts. Maton (2011) affirms that when the meaning of abstract concepts is closely related to the context, semantic gravity is said to be stronger (SG+), and weaker (SG-) when meaning is less related to the context. According to Maton (2011), the context may be social or symbolic.

Semantic density (SD) explores "the extent to which complex meaning is condensed within a symbol, term or idea, and the extent to which that idea is nested within a complex web of knowledge" (Walton & Rusznyak, 2020, p. 20). According to Maton (2011), semantic density can be stronger (SD+) and weaker (SD-), similar to semantic gravity. Semantic density is stronger (SD+) when the concept is related to more meanings/ideas, thus forming a network of ideas (Maton & Doran, 2017b). When the concept is simplified from its complex to simple form using everyday words, thereby comprising of fewer relations to other ideas, semantic density is said to be weaker

(SG-) (Maton & Doran, 2017a). The figure below is a semantic plane illustrating relative strengths of the semantic codes.

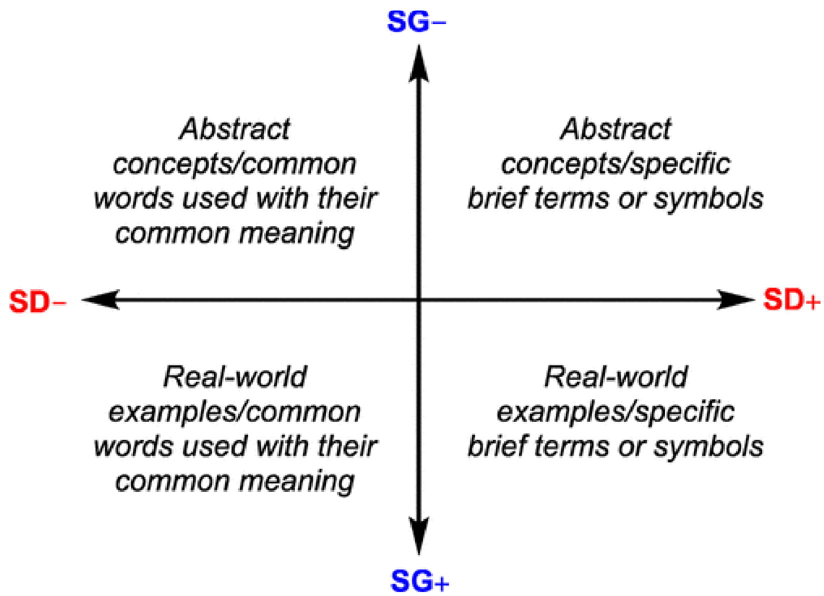


Figure 7: The semantic plane (Blackie, 2014, p. 464)

Figure 7 shows that concepts that lie in the upper left quadrant are less abstract as semantic density is weak (SD-), and not closely related to the context as semantic gravity is weak (SG-). For those concepts that lie in the upper right quadrant, Figure 7 shows that they are not closely related to the context and are related to a network of ideas (SD+, SG-). From the PLM framework, this quadrant would involve making links between scientific concepts, between different scales and levels of explanation at theoretical level, and between modes of representation. In the lower left quadrant, Figure 7 shows that the concepts have fewer relations to other ideas and are closely tied to the context (SD-, SG+). In the PLM perspective, this involves making links between every day and scientific ways of explaining through integration and differentiation, and between scientific explanations and real-world phenomena. Concepts lying in the last quadrant on lower right are said to be complex and strongly bound to the context of the concepts (SD+, SG+). From the PLM perspective, this quadrant would involve making links between analogous cases, and between different scales and levels of explanation at phenomenological level.

However, some ideas and/or concepts may be stronger and/or weaker than others in terms of semantic density and gravity. As such, it is necessary that the degree of strength, weak or strong, per semantic code be distinguished. This variation in each semantic code strength is illustrated in the tables below.

Table 3: Semantic gravity varying strengths (adopted from Cranwell &Whiteside (2020))

Strength	**Code**	**Indicator**
Weak	SG--	Using a *topic*-specific concept to link one or more scientific ideas together.
	SG-	Using a *subject*-specific concept to link one or more scientific ideas together.
	SG+	*Indirect* experiences (e.g. an outcome of an experiment) and/or general information is used as an example to elaborate on scientific statements or concepts.
Strong	SG++	Real-world examples / *direct* experiences (e.g. an experiment or everyday life encounter) are used as examples to elaborate on scientific statements or concepts.

Table 3above shows that the strength of semantic gravity can range from SG- to SG--, and SG+ to SG++. In this case, SG- represents weak semantic gravity strength while SG-- represents the weakest semantic gravity strength. In other words, an occurrence of SG-- indicates that the concepts covered during that period in a lesson are abstract, and furthest to learners' everyday lives and/or real-world situations followed by those of SG-. SG++ are in contrast to SG-- and indicate that the concepts covered during that period in a lesson are tied to the context, and greatly related to learners' everyday lives and/or real-world situations, followed by those in SG+. Therefore, a lesson delivered at SG-- level cannot necessarily be understood by anyone without specialisation or background knowledge in the subject and topic. Table 4below shows the strength and weakness of the semantic density.

Table 4: Semantic density varying strengths (adopted from Cranwell and Whiteside (2020))

Strength	**Code**	**Indicator**
Weak	SD--	*Subject*-specific concepts are not required to understand the – anyone can understand the explanation.
	SD-	Only one *subject*-specific concept is required to understand the explanation.
	SD+	Two or three *topic*-specific concepts are introduced and/or explained to enable understanding.
Strong	SD++	Four or more *topic*-specific concepts are introduced and/or explained to enable understanding.

Table 4 above shows that semantic density strength can range from SD- to SD--, and SD+ to SD++. When semantic density is at SD--, it is at its weakest level compared to SD-, as anyone can understand the explanation since it is not congested with scientific concepts. However, at SD++, a person without a good background knowledge in the topic or subject will not be able to understand the content since the semantic density strength is strongest with four or more concepts introduced and linked together to form a network of scientific concepts. The variation in strength assists in determining the level of abstractness of the content taught to learners during a lesson. As such, they are useful in understanding the teaching practices of these teachers before and after they participated in the intervention.

The relative strength of semantic codes can be traced over time and offer a graphical representation known as semantic profile (Maton et al., 2016). Semantic profiles graphically illustrate how knowledge building is promoted in a lesson over time from strengthening and weakening of semantic codes. Semantic profiles make use of semantic range which illustrate the distance between the highest and lowest strength of the semantic codes. When a teacher shifts across the different quadrants, as illustrated in Figure 7, the resulting semantic profile would be a semantic wave. A semantic wave traces the up and down movement as a teacher is strengthening and weakening the semantic codes within the semantic range (Maton et al., 2016). When the lesson resides in any one of the quadrants of the semantic plane in Figure 7, showing no movement or shift to other quadrants over time, a semantic flatline results (Maton et al., 2016). Figure 8below shows three different semantic profiles.

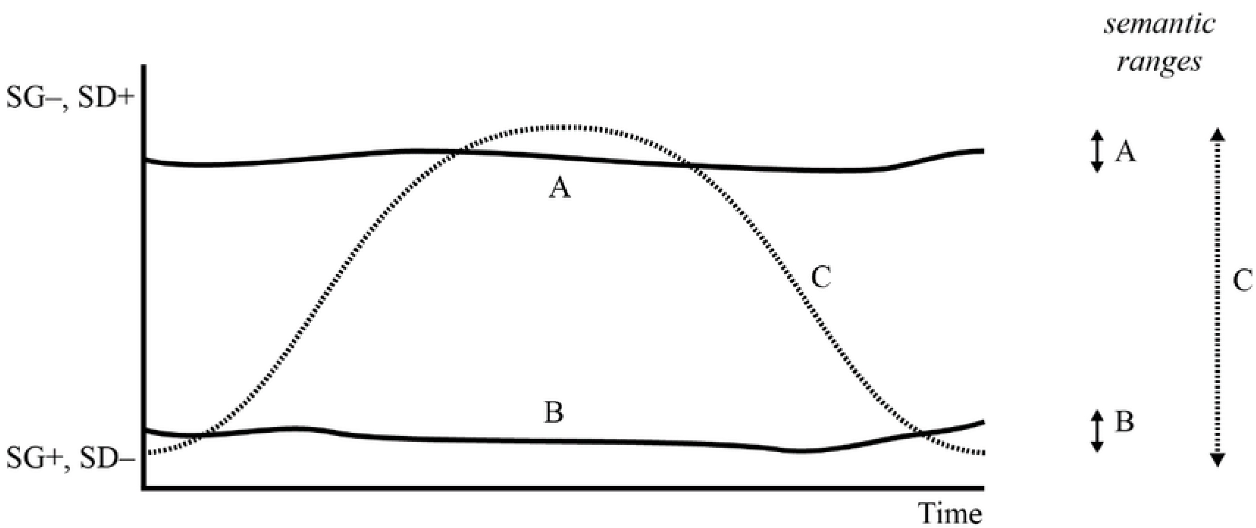


Figure 8: Three illustrative Semantic profiles (Maton et al., 2016, p. 17)

Figure 8 shows that semantic profile A is a high semantic flatline because it is at the highest point of the semantic range, where semantic gravity is weak while semantic density is strong. Semantic profile B is a low semantic flatline because the profile is residing at the lowest point of the semantic range, where the semantic gravity is strong while the semantic density is weak. Semantic profile C is a semantic wave, showing an up and down movement from the lowest to the highest point of the semantic range. Semantic profile showing semantic waves are preferred over semantic flatlines. This is because a semantic flatline in any one of the quadrants in the semantic plane could mean that (1) the knowledge is extremely condensed, or (2) the knowledge may be too general or closely tied to a context. In both cases, effective learning that promote understanding of scientific knowledge is hindered.

Effective knowledge building can also be hindered provided the teacher does not unpack and repack scientific knowledge accordingly. The figure below shows the resulting semantic profile of such a scenario.

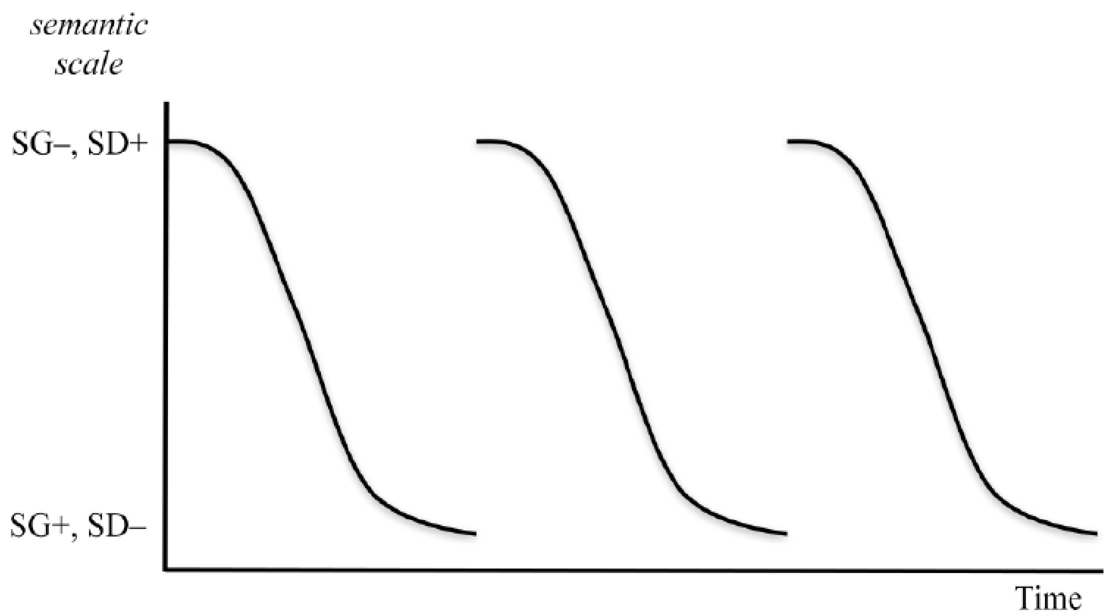


Figure 9: A down escalator semantic profile (Maton, 2014, p. 40)

Figure 9 shows a semantic profile of a lesson that started with a strong semantic density. The concept/knowledge of strong semantic density is unpacked by providing examples from everyday life, thereby increasing the strength of semantic gravity. However, the knowledge is not repacked after the example to increase the semantic density strength, thereby creating a semantic wave. This results in gaps between the concepts taught. This type of semantic profile is known as a 'down escalator'. Instead of down escalator, a lesson can have an 'up escalator' whereby the lesson may start with examples from the context (SG+) and proceed towards strong semantic density. However, there will be no unpacking from SD+ to SG+, leaving gaps between the concepts. Similar to semantic flatlines, the up and down escalators are not preferred because they prevent learners from seeing and benefitting from the systematic nature of scientific knowledge since knowledge is being presented as unrelated fragments, each concept standing on its own and unrelated to the other concepts.

3.5. INTEGRATION OF PLM AND LCT

The semantic dimension of the legitimation code theory (LCT) offers a visual representation of the lesson over time, through the use of semantic profiles, shown in Figure 8 and Figure 9 above. However, these semantic profiles can only be drawn through meticulous articulation of the varying semantic codes strength, as shown in Table 3 and Table 4 above. Such affordances are unavailable in the pedagogical link making (PLM) framework, although it offers an understanding of how knowledge building was promoted during a lesson, similar to LCT. The lack of this visual representation provides a limited view of the lesson over time and present information in a rather fragmented format without showing a link between the different approaches. It is therefore, for this reason that this study integrated the PLM framework into the semantic dimension of LCT to analyse the lessons of the novice Physical Sciences teachers before and after participating in the intervention. The integration of the LCT and PLM is represented in Table 5below.

Table 5: LCT and PLM Integration

Identifying indicator one	Identifying indicator two	SG Strength	SD Strength
Making links between every day and scientific ways of explaining	Integration	SG++	SD-
	Differentiation	SG++	SD-
Making links between scientific concepts	Linking scientific concepts	SG--	SD++
Making links between scientific explanations and real-world phenomena	Simple phenomena	SG++	SD+
	Complex phenomena	SG+	SD+
Making links between different scales and levels of explanation	Phenomenological	SG--	SD++
	Theoretical	SG--	SD++
Making links between modes of representation	Symbolic	SG--	SD++
	Pictorial	SG++	SD--
	Diagrammatic	SG-	SD+
	Chemical equations	SG--	SD++
	Graphical	SG--	SD++
Making links between analogous cases	Analogies	SG++	SD+

Table 5 above shows that when links between every day and scientific ways of explaining are made using integration and/or differentiation, it involves the use of information from direct experiences (SG++) while focusing on only one subject/topic specific concept (SD-). When making links between scientific concepts, different scales and levels of explanation, and modes of representation using symbols; chemical equations and graphs, learners must have a fundamental scientific background knowledge. In other words, unless one has fundamental scientific knowledge, they will not be able to understand the content of the lesson. Hence, semantic density strength is highest, residing at SD++, while semantic gravity is weakest, residing at SG--, in these knowledge building approaches.

When making links between analogous cases as well as scientific explanations and real-world phenomena using simple phenomena, Table 5 above shows that both semantic codes remain strong, with semantic gravity residing at SG++ while semantic density remains at SD+. This indicates that although these links draw on information from learners' direct everyday life experiences, while two or three scientific concepts are introduced. In terms of using complex phenomena to make links between scientific explanations and real-world phenomena, Table 5 shows that information from indirect experiences is used to enable an understanding of two or three scientific concepts. Hence, both semantic gravity and density are equally strong, providing an SG+ and SD+ strength.

Table 4 shows that pictures may also be used to make links between different modes of representation. These pictures are visual representation of learners' direct experiences, and anyone without any scientific knowledge background may be able to deduce meaning from them. As such, when used in a lesson to make pedagogical links, semantic density remain weakest, SD--, while semantic gravity is strongest, SG++. This is in contrast to using scientific diagrams, which require one to have some scientific knowledge background to understand them as it involves the use of few scientific concepts. Thus, semantic codes strength lies at SG- and SD+. This integrated version of PLM framework and LCT was useful in analysing the lessons of the novice Physical Sciences teachers to determine whether there was a change in their teaching practice after participating in the blended professional development intervention, thereby indicating the extent into which the intervention was effective.

3.6. SUMMARY OF THE CHAPTER

This chapter has discussed how teacher efficacy is an invisible driving force that determines the success of any professional development intervention. Teacher efficacy was reviewed from a classroom perspective, as classroom efficacy, and professional point of view, as professional efficacy. Classroom efficacy examines teachers' beliefs about their own capabilities in terms of teaching to enable learning, as influenced by the teachers' subject content knowledge (SCK) and pedagogical content knowledge (PCK). Professional efficacy examines the teachers' working environment, looking at how they identify with their teaching subject, develop their careers within their subject and create professional networks. Hence, it is influenced by professional networking, professional identity, and career development. This chapter has further discussed the influence classroom efficacy can have on professional efficacy and vice versa, in relation to novice teachers as well as off-field teachers.

This chapter has also discussed the pedagogical link making (PLM) framework as a conceptual framework tool used to understand how knowledge building is promoted during a lesson. Due to the inability of the PLM framework to show how a teacher shifts across the different PLM approaches as they promote knowledge building during a lesson, this study has employed the Semantic dimension of the LCT. This dimension of LCT offers a visual representation, known as semantic profile, illustrating the manner in which a teacher would introduce, unpack, and pack concepts over time during a lesson while shifting between the different PLM approaches, thereby promoting knowledge building. Therefore, the PLM framework and semantic dimension of LCT were integrated to develop an analytical framework, depicted by Table 5, useful in understanding how knowledge building was promoted during the lesson over time. Chapter Six will show the operationalisation of this framework in data analysis. Before then, a detailed framework of the blended professional development intervention whose effectiveness in changing teaching practice is being examined by this study is necessary and presented in the next chapter.

CHAPTER FOUR: RESEARCH DESIGN - INTERVENTION FRAMEWORK

4.1. INTRODUCTION

The purpose of this study was to examine the effectiveness of a blended professional development intervention in rural schools of Mpumalanga on the teaching practices of novice Physical Sciences teachers. The aim of the intervention was to assist Physical Sciences teachers in teaching the content of the subject to Grade 12 learners. The intervention also aimed to provide the teachers with strategies that would help them to prepare their learners for the final examination while also improving their pass rate and performance. The details of how the two purposes of the intervention were addressed are presented in this chapter.

4.2. INTERVENTION MODEL

The two purposes of the intervention outlined above indicate that its overall purpose was transformative in nature as it intended to shape the way the teachers who participated in the intervention were currently teaching and, consequently, improve learner performance. As such, it adopted the transformative model which, according to Kennedy (2005), involves an effective combination of a range of models to support a transformative agenda. The transformative model of the intervention incorporated the training model, which is transmissive in nature, and the community of practice model, which is translational in nature, to promote professional development of the teachers, as illustrated in Figure 10 below.

According to Kennedy (2005), the training model is typically used as an opportunity for teachers to upgrade their skills and improve competence. In the intervention, the training model was used to show teachers how to teach certain topics in the Grade 12 Physical Sciences curriculum. It was also used to show them the structure of Physical Sciences examination papers and that can be used to improve the learners' pass rate. To address the abovementioned use of the training model, Figure 10 below shows that the intervention facilitated face-to-face and online workshops. As this model typically promote passive participation (Kennedy, 2005), teachers were not proactive during the intervention workshops. They spent their time listening to the facilitators during the online and face-to-face workshops.

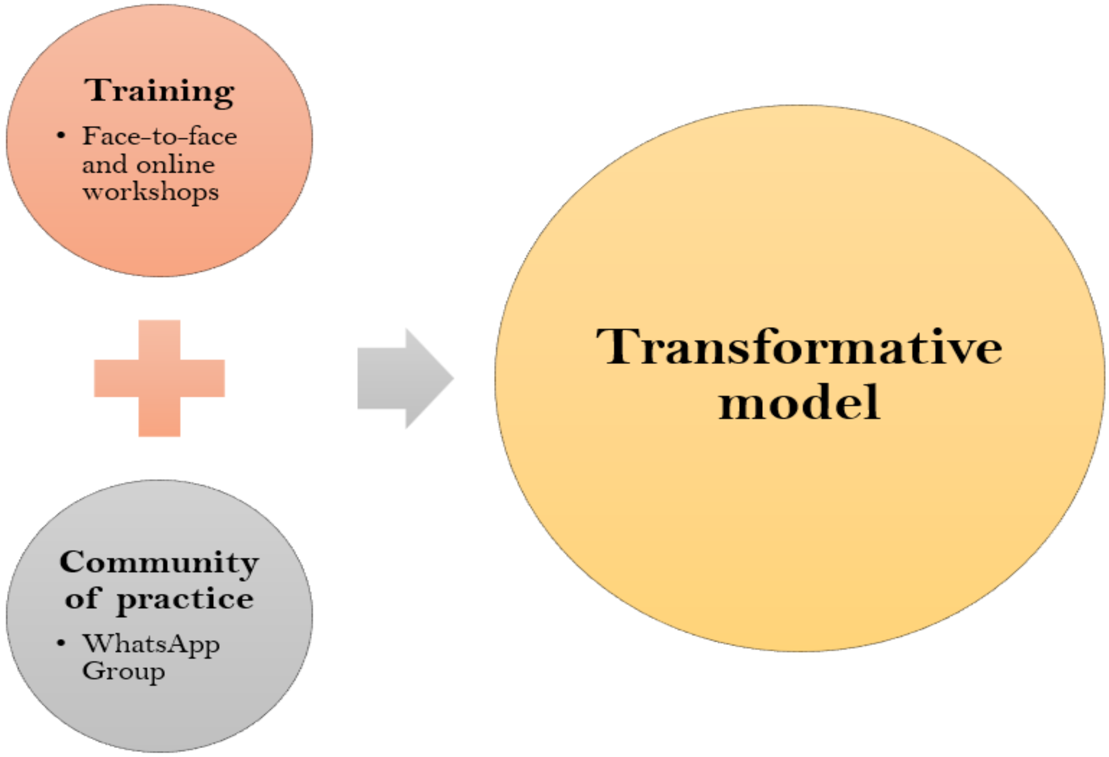


Figure 10: Intervention Model

As illustrated in Figure 10 above, the community of practice model was also employed as part of the transformative model during the intervention. The community of practice model is characterised by the interactions of more than two individuals (Kennedy, 2005). In the intervention, this model of professional development was used as support structure for teachers where they could share ideas and assist one another, where necessary. Since the intervention was administered while the COVID-19 pandemic was at its peak, with restrictions to movement and gatherings in place, Figure 10 shows that WhatsApp was used as a platform to enable the community of practice interactions. Utilising WhatsApp to establish the community of practice diminished restrictions posed by geographical factors that are preventing teachers from taking advantage of professional development opportunities. These geographical factors include, amongst others, geographical isolation (Mukeredzi, 2013) caused by the considerable distance between schools within the circuit of a district. Using WhatsApp, all the teachers could participate in the discussions. This next section provides a detailed description of the intervention using the blended professional development framework outlined in Figure 4.

4.3. FEATURES OF THE INTERVENTION

This section makes reference to Figure 4 in discussing each feature of the blended professional development intervention offered to the novice Physical Sciences teachers. The technological pedagogical content knowledge (TPCK) feature is not discussed here because it relates to the knowledge a facilitator should possess to effectively facilitate blended professional development interventions and shape teaching practice. This aspect, TPCK, is therefore beyond the scope of this study.

4.3.1. Content Focus

The professional development intervention was focusing on the Grade 12 Physical Sciences teaching and learning. As such, the workshops were focused on Grade 12 Physical Sciences topics and how to teach them. Table 6 shows the topics that the teachers were workshopped on during the intervention.

Table 6: Topics of the intervention workshops

Workshop no.	Workshop topic	Component of Physical Sciences
1	Electrodynamics	Physics
2	Electrochemistry	Chemistry
3	Newton’s Laws	Physics
4	Vertical projectile Motion	Physics
5	Acids and bases	Chemistry
6	Rates of Reactions and Chemical Equilibrium	Chemistry
7	Newton’s Laws	Physics
8	Organic Chemistry	Chemistry

Table 6 above shows that the teachers were workshopped on four different topics from the Chemistry component of Physical Sciences. In the Physics component of Physical Sciences, Table 6 shows that only three different topics were covered. Newton’s Laws were done twice, during workshop 3 and 7. These topics were selected based on their allocation of marks in the examination and performance of learners on these topics over the years. The weighting of the different topics in the Physics component of Grade 12 Physical Sciences are shown in Table 7 below.

Table 7: Weighting of topics in Physics Grade 12 Examination (adopted from DBE, 2021)

Topic	Sub-topics	Mark (out of 150)	Percentage
Mechanics	Momentum and Impulse, Newton's laws, Vertical projectile Motion, Work, Energy & Power	65	43.3
Waves, Sound and Light	Doppler Effect	15	10
Electricity and Magnetism	Electric circuits and Electrodynamics	55	36.7
Matter and Material	Optical phenomena and properties of materials (photo-electric effect, emission, and absorption spectra)	15	10

Table 7 above shows that Mechanics weighs most marks than all the other Physics topics. As such, three, out of the four Physics workshops were on Mechanics (workshop 3, 4 and 7). Table 7 shows that Electricity and Magnetism is the second topic that weighs most marks. As such, a workshop on Electrodynamics only was conducted, as shown in Table 6 above. Electrodynamics was selected because it is the only sub-topic in Electricity and Magnetism that is introduced in Grade 12. Electric Circuits is introduced in earlier grades. Teachers were not workshopped on the other topics of Physics as they weigh least marks with better learner performance. Table 8below shows the weighting of the different topics in the Chemistry component of Grade 12 Physical Sciences.

Table 8 below shows that the content of Chemical Systems is no longer examinable, based on the amended Curriculum which will be implemented until the end of 2024. As such, no workshops were held under this topic. The teachers were workshopped on all the sub-topics of Matter and Material and Chemical Change, as shown in Table 6 above. In the examinable topics, Table 8 shows that Chemical Change, which comprises of four different sub-topics, weighs the most marks in the second paper, Chemistry component, of Grade 12 Physical Sciences.

Table 8: Weighting of topics in Chemistry Grade 12 Examination (adopted from DBE, 2021)

Topic	Sub-topics	Mark (out of 150)	Percentage
Matter and materials	Organic chemistry	58	38,7
Chemical change	Reaction rate, Chemical equilibrium, Acids and bases, and Electrochemical reactions (Electrochemistry)	92	61,3
Chemical systems	Chemical industry (fertilizer industry)	0	0

Desimone (2009) and Patton et al. (2015) posit that professional development of teachers should focus on the content knowledge, and how learners conceptualise that knowledge. According to Jita and Ndlalane (2009), targeting these knowledge areas can change teachers' classroom practices. Therefore, this intervention ensured that for each topic teachers were workshopped on strategies on how to teach the topic to enable learning were shared while revising the topic-specific content knowledge. The workshops started with an identification of misconceptions that learners may have about each topic that was identified. Thereafter, strategies on how to address the identified misconceptions were shared with the teachers. While sharing strategies on how to teach topics and address misconceptions, the content knowledge of the topics covered was revised, whereby teachers were occasionally asked questions on the topics and some concepts explained for them.

Also, some of challenges on each topic and strategies on how to address those identified challenges were shared with the teachers.

4.3.2. Coherence

Kaino et al. (2015) argue that teachers' professional development should be coherent, be based on the needs and interests of the teachers and should be grounded on the improvement of learners' achievement. It should also be aligned to the needs and interests of learners as well as the DBE goals, and the goals of the schools (Bayar, 2014). As such, all the teachers who participated in the intervention were required to complete a questionnaire before the intervention workshops were to be conducted. The questionnaire sought to determine their teaching and learning needs, including topics they needed professional development on. The topics that teachers found as challenging and needed assistance with are presented in Figure 11 below.

The intervention consisted of a total of 13 teachers from various quantile 1-3 schools within a circuit of a district in the rural areas of Mpumalanga province. Figure 11 below shows that most teachers identified the topic of acids and bases as challenging. The second most challenging topic for the teachers was electricity. This topic was followed by organic chemistry and chemical equilibrium, respectively. The topics that teachers were workshopped on were partly informed by the analysis of these questionnaires. Hence, teaching and learning strategies were shared with the teachers to enhance their content and pedagogical content knowledge on some of the topics identified in Figure 11 below.

Since research shows that teachers engage in professional development to improve the performance of their learners (Letloenyane & Jita, 2020), strategies on how to improve the performance of their learners were shared with the teachers during the intervention workshops. Teachers were guided on how questions are structured in the exam, in terms of cognitive levels and percentage contribution of each cognitive level. Teachers got to learn that all learners may obtain at least 30% in their exam, 15% in paper one and 15% in paper two, which is equivalent to 15% of Physical Sciences Examination. This is because 15% of the questions in the examination, that is, 7,5% in paper one and 7,5% in paper two, are low order questions which require the learners to simply recall the information. This means that if learners can obtain the 15%, they will need only 15% to pass the subject. Strategies on how learners can obtain the remaining 15% in the understanding and application questions were shared with the teachers. Such information was meant to help teachers to identify the concepts to concentrate on during lessons to aid the learners understanding and performance.

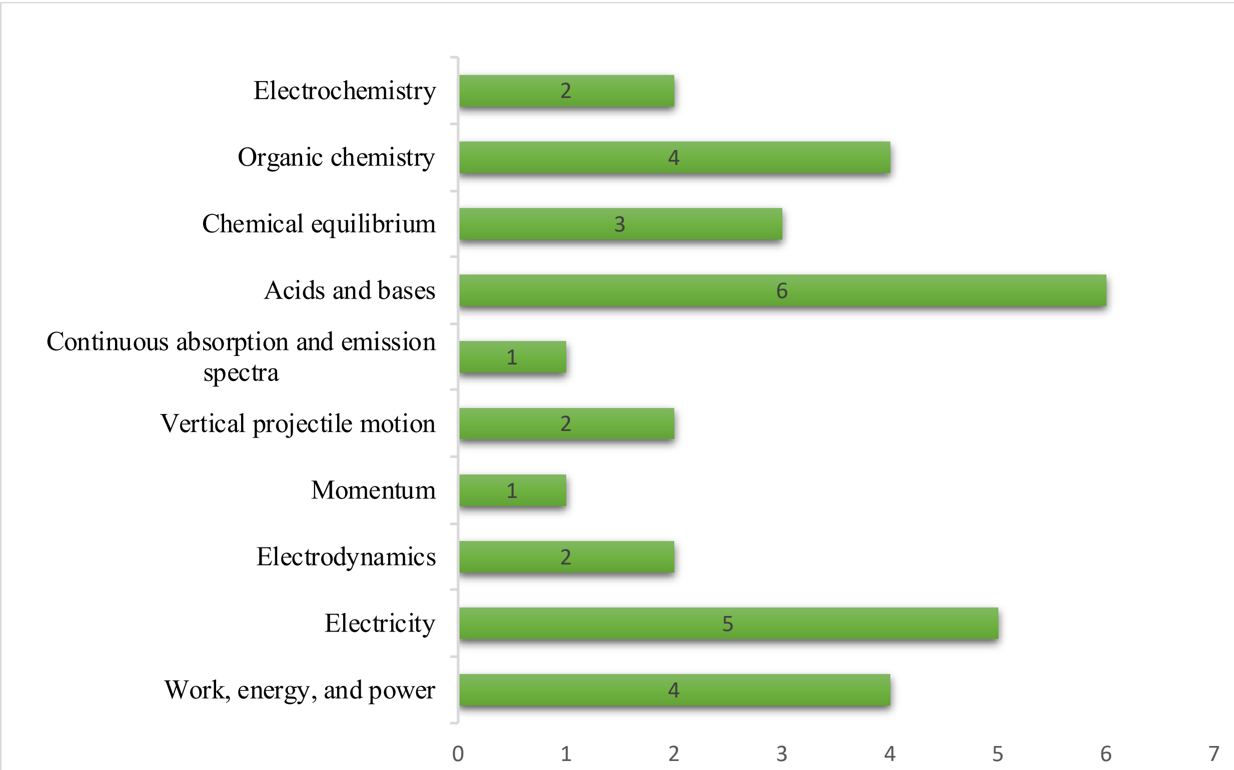


Figure 11: Topics identified as challenging by teachers.

Furthermore, workshops 5 and 6, which were focused on some of the Chemistry topics found challenging by some teachers, were conducted few days before the learners wrote paper two of the Physical Sciences preliminary examination. As a result, some school teachers, such as Mr Jones, joined the workshops with their learners. However, facilitators were not aware of this arrangement. As such, learners could not ask questions on their own, they had to rely on their teachers to ask the questions on their behalf. These strategies addressed the second purpose of the intervention, which was to improve performance of learners in this subject. These strategies were also aligned to the needs and interests of the learners, DBE, and schools, as the schools in this circuit were selected based on their poor performance in Physical Sciences.

4.3.3. Active engagement

According to Desimone (2009) and Patton et al. (2015), teachers must be treated as active learners during their professional development. Mushayikwa (2009) and Patton et al. (2015) add that hands-on engagement with teachers is more beneficial than training teachers. Therefore, active participation may involve observing teachers while teaching and providing them with constructive feedback. In this intervention, teachers were not required to prepare any lessons for observation by the organisers and facilitators. Teachers were also not followed into their classroom with the purpose of providing support and feedback based on their teaching approach and implementation of the shared teaching and learning strategies.

The teachers were given templates to use to reflect on their lessons while participating in the intervention. These written reflections were to be collected and analysed by the facilitators. The analysis would show the teachers' strengths and areas of development. The areas of development that were identified were to be used to develop the teachers further professionally, enhancing their competency in the teaching of Physical Sciences. Since no facilitators visits and coaching/mentoring was planned for the teachers, these reflections would keep the intervention organisers up to date with what teachers can and cannot do. However, teachers did not submit their reflections, which could have been used to promote active engagement and to keep the facilitators up to date with the level of development of the teachers. The subject advisor explained that the teachers were too busy, so did not have sufficient to complete the post-workshop reflections. As such, teachers were occasionally requested to verbally reflect on their experiences of implementing the shared teaching and learning strategies before the commencement of intervention workshops.

Active participation entails active involvement during the intervention workshops through question-and-answer sessions during the workshops. Such sessions, according to Patton et al. (2015), allow teachers to voice out their thinking as they are being professionally developed, thereby acknowledging learning as a social process. In this intervention, teachers were occasionally asked open-ended questions related to the subject matter knowledge and pedagogical content knowledge during the workshops. However, teachers spent most of the time in the workshops listening to the facilitator with little to no engagement. Although this is a concern, since active participation is one of the effective components of professional development, the focus of this study was on the teachers, and not facilitators, thus no appropriate justification could be given regarding this aspect.

Another method of encouraging active participation through hands-on experience would be to give activities to teachers to complete individually and/or in peers or groups. The activities must be related to subject content knowledge and pedagogical content knowledge. Teachers may not need to do a formal presentation of their responses to the activities; however, they must be given constructive feedback by their peers and facilitators. As fruitful as such activities may be, they were not given to teachers. Teachers were not given any activity to complete during the intervention. As such, teachers were mostly passive participants during the intervention workshops, occasionally responding to questions asked.

4.3.4. Collaboration

Desimone (2009) contend that teachers' professional development must encourage collaboration, where teachers from the same schools or across schools professionally develop one another. Since the intervention was administered during the peak of the COVID-19 pandemic, close interactions, such as group and peer discussions, were restricted, thus, opportunities for teachers to seek assistance were limited. This is in addition to the barrier caused by the distance between the schools. To bridge this gap, a WhatsApp group had been set up for teachers to use to seek assistance from the facilitators and fellow colleagues at any time of the day. As such, this WhatsApp group comprised of the teachers and subject specialists from the Mpumalanga DBE. These included subject advisors and subject coordinators at provincial, district, and circuit level. The WhatsApp group also comprised of organisers of the intervention, which included lecturers of Physical Sciences from the same tertiary institution in South Africa. These lecturers were also facilitators of the workshops, with years of experience in teaching Physical Sciences at both school and tertiary level.

The WhatsApp group was also used for sharing of teaching and learning information and materials. For this purpose, links of videos that teachers could use and share with their learners for additional source of information on a topic/concept were shared with the teachers. The WhatsApp group was also used for ease of communication between organisers and teachers as well as fellow colleagues.

Reminders of workshops were shared with the teachers, including links to the online workshops. This study acknowledges that the WhatsApp platform could have been used to contribute meaningfully to the teachers' professional development through facilitated exchanges. However, such potential was not utilised.

4.3.5. Individual support

According to Figure 4, provisions, such as coaching and mentoring sessions, must be made to enable individual support. This aspect is in addition to collaboration opportunities amongst teachers. According to Hunt-Barron et al. (2015), individual support allows teachers some privacy whereby they can directly engage with their facilitators on any concern they may have instead of posting such concern on a public platform, such as WhatsApp, where everyone can see it. Figure 4 shows that such support can be provided through the introduction of coaching and/or mentoring models, discussed in Section 2.2 above. In the intervention, these models were not employed. However, teachers could engage with their facilitators during short breaks or before and after each workshop. No restrictions were posed in terms of when the teachers could interact with their facilitators.

4.3.6. Duration

Kaino et al. (2015) contends that teachers' professional development should be of longer duration to allow teachers sufficient time to digest what they have learnt. For this intervention, the duration of the intervention was decided by the organisers. However, the dates and time of the workshops were decided and agreed upon in consultation with the teachers. The intervention took a total of 16 hours, where teachers were workshopped on the topics outlined in Table 6 above. The breakdown of these hours is shown in Table **9** below.

Table **9** below shows that the first and second workshops were conducted on the same day. Likewise, workshops seven and eight were conducted on the same day. These workshops were conducted in two different schools within the circuit and were face-to-face with the teachers. The third, fourth, fifth and sixth workshops were conducted online using Microsoft Teams. The online workshops were recorded, and the recordings were emailed to teachers after each workshop. The online workshops were held on Wednesdays and Fridays on the dates shown in Table **9** below. On the outlined dates, the online workshops started at 15H00 and ended at 17H00. The duration of each online workshop was 2 hours, and 4 hours for face-to-face workshops as two topics, 2 hours each, were addressed. Although teachers were the ones who agreed to this time for the online workshop, there is a possibility that their participation was affected due to work related interferences.

Table 9: Intervention workshops mode and duration

Workshop no.	Date	Workshop topic	Workshop mode	Duration
1	21-Aug-21	Electrodynamics	Face-to-face	2 Hours
2	21-Aug-21	Electrochemistry	Face-to-face	2 Hours
3	01-Sep-21	Mechanics	Online	2 Hours
4	03-Sep-21	Vertical projectile Motion	Online	2 Hours
5	15-Sep-21	Acids and bases	Online	2 Hours
6	17-Sep-21	Rates of Reactions and Chemical Equilibrium	Online	2 Hours
7	02-Oct-21	Mechanics	Face-to-face	2 Hours
8	02-Oct-21	Organic Chemistry	Face-to-face	2 Hours

Table **9** shows that the last two workshops, workshop 7 and 8, were different to all the other workshops because learners were directly involved. For these two workshops, teachers were invited to a different school from the one used during the first workshop. At this school, the facilitator taught Mechanics and Organic chemistry to the Grade 12 Physical Sciences learners. During this workshop, teachers were shown how they are expected to use the teaching and learning strategies shared with them throughout the intervention period to improve conceptual understanding and performance of learners in the subject. As such, teachers took on the role of the observer during these two workshops, observing the facilitator teach the Grade 12 Physical Sciences learners.

4.3.7. Digital tools

Figure 4 shows that for blended professional development to achieve its purpose, it should make provision for digital tools, which include data bundles and/or laptops. According to Marongwe and Garidzirai (2021) and Mukuna and Aloka (2020), making provision for digital tools enables access to online learning. For this intervention, the teachers were not provided with any resources to enable their access to online workshops. They joined the online workshops at their own expense. This was mainly the result of financial constraints. Furthermore, the organisers seemed to assume that all schools have got access to internet for teachers. Teachers were also expected to have smart phones and/or laptops that they could use to participate in online workshops.

4.3.8. Sustainability

According to Desimone (2009) and Patton et al. (2015), teachers' professional development should be sustainable, meaning that teachers should be able to use the knowledge and skills that they learn during the intervention to continuously develop themselves. As part of enabling sustainability in this intervention, teachers were provided with three teaching resources during the first workshop. The first teaching resource was micro kits. These micro kits contained small-sized apparatus for Chemistry and Physics experiments. Each teacher received one micro kit for Chemistry and another one for Physics. The micro kits were distributed for teachers to use them to demonstrate physical and chemical phenomenon during their lessons. These micro kits were distributed during the workshops held on the 21st of August 2021. Hence, those who did not attend workshops 1 and 2 did not receive the micro-kits.

The second teaching resource was an examination guideline that teachers were to use as reference as they prepare their learners for examinations. The last teaching resource was a booklet consisting of previous question papers from various provinces. For each topic, previous questions from at least three provinces were put together. For example, previous questions on vertical projectile motion from three different provinces would be compiled together into a booklet. These booklets were developed to help learners to get used to examination structures, thereby motivating them to perform better in their final examination.

These teaching resources can be used by the teachers after the intervention. The examination guideline and booklet were readily accessible to the teachers. The practical materials can be used to aid teaching and learning of various topics under Electricity and Magnetism and Chemical Change. The booklets can be used yearly with minor changes to prepare the learners for the summative and formative assessments, such as tests and examinations. The shared teaching and learning strategies are transferrable, thereby applicable in all Physical Sciences topics. Overall, teachers are expected to use the knowledge and skills they have learnt during the intervention to continuously develop themselves, thus enabling sustainability.

According to Mushayikwa (2009), sustainability can also be accomplished through practical demonstration of the knowledge taught during professional development interventions. In this intervention, the knowledge and skills teachers were expected to learn were practically demonstrated during workshops 7 and 8. During these workshops, the facilitator used available resources from the school to conduct the lessons with the learners. This made it easier for teachers to see the applicability of the teaching and learning strategies shared in their own contexts as the school where the workshops were conducted was poorly resourced with poor infrastructure.

4.4. SUMMARY OF THE CHAPTER

This chapter has used the features of effective blended professional development to outline the design of the professional development intervention administered to thirteen teachers in the rural schools of Mpumalanga province. This chapter has indicated that the intervention was focused on Grade 12 Physical Sciences topics, four chemistry topics and three Physics topics. The intervention workshops were focused on enhancing teachers' content knowledge of these topics. Strategies of teaching these topics and how to improve the pass rate of learners in Physical Sciences were also shared with the teachers. This chapter has explained that the intervention was 16 hours long with each workshop running for 2 hours. Due to the intervention being conducted during the peak of the COVID-19 pandemic in 2021, some workshops were conducted online using Microsoft Teams while others were conducted face-to-face. In addition, a WhatsApp group was created to establish a community of practice amongst the teachers and their superiors. The next chapter will detail the methodology adopted to address the purpose of this study.

CHAPTER FIVE: RESEARCH DESIGN - METHODOLOGY

5.1. INTRODUCTION

This study aimed to determine the effectiveness of a blended professional development intervention on the teaching practices of novice Physical Sciences teachers in rural schools of Mpumalanga province. In response to this main aim, the following research questions were addressed:

1. What are the teaching and learning needs of novice Physical Sciences teachers in the rural schools of Mpumalanga province?
2. What are the views of the novice Physical Sciences teachers about the effectiveness of the blended professional development intervention workshops?
3. In what ways has the teaching practices of novice Physical Sciences teachers changed after participating in a blended professional development intervention?
4. How were the identified teaching and learning needs of novice Physical Sciences teachers in the rural schools of Mpumalanga addressed by the blended professional development intervention?

The design of the professional development intervention has been presented in the previous chapter. In this chapter, the methodology that was followed in addressing the purpose of this study is discussed. The discussion covers the research paradigm informing this study, a description of the research approach used, the research design used, as well as the ethical procedures followed in an endeavour to address the purpose of this study. It also includes a discussion of the sampling techniques used to sample the participants of this study and the methods used to collect data. Furthermore, this chapter provides a description of the role of the researcher during the teachers' professional development intervention.

5.2. RESEARCH PARADIGM: INTERPRETIVISM

Research studies are often guided by the researcher's philosophical worldview known as a paradigm. A paradigm refers to a set of beliefs brought forth by the researcher in the research process (Creswell & Creswell, 2018). According to Creswell and Poth (2018), a paradigm influences the type of research questions a researcher asks, how the research will be carried out and how data will be analysed. This study adopted the interpretivism paradigm because it endeavours to understand human experiences from the point of view of individuals experiencing the phenomenon under investigation (Cohen et al., 2011). The paradigm allows a researcher to understand the participants' lived experiences regarding a phenomenon. As such, the interpretivism paradigm enabled a better understanding of the effectiveness of the blended professional development intervention on the teaching practices of novice teachers in rural schools of the Mpumalanga province. This was through the analysis of their responses from the interviews, lesson observations and field notes which are all detailed below.

5.3. RESEARCH APPROACH: QUALITATIVE RESEARCH

The aim of this study was to examine the effectiveness of a blended professional development intervention on the teaching practices of novice Physical Sciences teachers in rural schools of Mpumalanga province. This involved understanding how these teachers were teaching before and after participating in the blended professional development intervention. Such an understanding emanated from spending extensive time with the teachers. Thus, this study employed a qualitative research approach because it is interested in "understanding how people interpret their experiences, how they construct their worlds, and what meaning they attribute to their experiences" (Merriam & Tisdell, 2016, p. 6). Cohen et al. (2011) add that this research approach provides an in-depth understanding of the phenomenon of interest and unearth issues lying beneath the surface. As such, it is a suitable research approach for this study as it enabled a comprehensive view of the professional development support given to novice teachers in the rural schools of Mpumalanga.

5.4. RESEARCH DESIGN: MULTICASE STUDY

Research designs are types of research strategies within the research approaches "that provide specific direction for procedures in a research study" (Creswell & Creswell, 2018, p. 11). This study assumes the case study design which is "an in-depth description and analysis of a bounded system" (Merriam & Tisdell, 2016, p. 37). According to Merriam and Tisdell (2016), a case is a bounded unit defined by characteristics of a group, individual or geographical parameters. In this study, all the teachers form a single case in the sense that they are all teaching Physical Sciences, a subject of interest to this study, and they are novices in the teaching of this subject. However, some of them are qualified to teach the subject while others are not, thus forming two cases. Additionally, all three teachers are from different schools within the circuit, a sub-unit of a district, in the Mpumalanga province, thereby forming multiple cases. This research design is suitable for this study because it provides a deeper understanding of the research problem, thereby correlating with the interpretivism research paradigm of this study.

5.5. SAMPLING OF RESEARCH PARTICIPANTS

Sampling is a process of selecting study subjects from a larger population (Leavy, 2017). According to Leavy (2017), a population refers to a group of people with certain characteristics that are of interest to the study. The individual study subjects that may be selected from the larger population of interest are called the study sample. There are numerous ways in which a sample may be selected from a larger population. This includes purposive sampling, amongst others. Purposive sampling method was used to select the sample of this study. Purposive sampling involves selecting a research sample from a larger population by assessing the richness of information the sample may bring to address the purpose of the study (Leavy, 2017). This sampling method is also known as judgmental sampling because it is subjective and selective. However, its nature enables the collection of rich data. As such, this study used purposive sampling method to target novice teachers with not more than five years of experience in teaching Physical Sciences at Grade 12 level since the intervention workshops were focusing on Grade 12 content.

During strategic meetings, subject advisors presented a profile of Physical Sciences teachers in the selected circuit and their working environment. From the presentation, the researcher learned that there are thirteen Physical Sciences teachers within the circuit in which the intervention was being administered. All thirteen teachers participated in the intervention, except for one who was on maternity leave. From the thirteen teachers in the circuit, only five teachers had less than five years of experience teaching Physical Sciences at Grade 12 level. From the five teachers, two were female and the other three were male. One of the female teachers went for maternity leave before the commencement of the intervention. As such, she did not participate in the study at all, nor did she participate in the intervention. The remaining female novice teacher withdrew her consent to participate in the study post intervention, thus, all the data obtained from her before the intervention and during the intervention was not used in any part of this study. As a result, only three teachers who are novices in teaching Grade 12 remained from the thirteen teachers in the circuit who participated in the intervention. The three teachers were selected as a sample for this study. The three teachers involved in the study were Mr Smith, Mr Brown, and Mr Jones *(these names are pseudonyms given to the teachers for protection of their identity)*. The profiles of these teachers are outlined in Table 10 below.

Table 10: Teachers' profile

Teacher	Qualifications	Teaching Subjects	Teaching experience	Grade 12 PS Teaching Experience
Mr Brown	Bachelor of Education	Physical Sciences and Mathematics	2	2
Mr Jones	BSc in Mathematical Sciences and Statistics, PGCE; Pursuing BSc Hons in Statistics	Mathematics and Technology	3	3
Mr Smith	BSc in Physics and Applied Mathematics, PGCE	Mathematics and Natural Science	16	2

Table 10 above shows the profiles of each teacher involved in this study. The first teacher in Table 10 above is Mr Brown who has two years of teaching experience and has been teaching Physical Sciences from 2019. Mr Brown is a Bachelor of Education graduate, specialising in Mathematics and Physical Sciences. The second teacher in Table 10 above is Mr Jones, who holds a Bachelor of Science degree, specialising in Mathematical Science and Statistics. Mr Jones has a Post Graduate Certificate in Education (PGCE), specialising in Mathematics and Technology. Currently, Mr Jones is pursuing an Honours degree in Mathematical Science and Statistics. Mr Jones has been teaching Physical Sciences from 2018. The third teacher in Table 10 above is Mr Smith who is also holds a Bachelor of Science degree, specialising in Physics and Applied Mathematics. Just like Mr Jones, Mr Smith has a PGCE, specialising in Mathematics and Natural Sciences. Mr Smith teachers Mathematics and has 16 years of teaching experience.. However, he started teaching Physical Sciences in 2020 at the same school he has been teaching at for the past 16 years. Although this teacher cannot generally be categorised as a novice teacher if one was to focus only on his years of teaching experience, he, however, fits this category because he has less than two years of experience in teaching Physical Sciences at Grade 12. In this case, being a novice is not limited to years of teaching experience, it also considers years of experience in each grade and subject due to changes in knowledge and complexity.

5.6. CONSIDERATION OF ETHICAL ISSUES

Before a study is conducted, a research ethics application needs to be submitted to the ethics committee for ethical clearance to be granted. Research ethics refers to ethical practices which "involve morality, integrity, fairness, and truthfulness. Morality is about knowing what is right and wrong, and integrity is about acting on that knowledge" (Leavy, 2017, p. 24). Ethical research practices include the researcher being truthful about the purpose of the study to ensure that participants make informed consent to participate in the study (Gefenas, 2006). Fairness refers to the mutual benefit principle where the research meets the interests of both parties, that is the researcher and participants (Gefenas, 2006). It also includes providing participants with an opportunity to consent to participate or not participate in the study without being disadvantaged if they decide not to participate.

Ethical research practice also includes the protection of the research participants. In South Africa, the Protection of Personal Information Act 4 of 2013 speaks to research ethics that research participants need to be protected through non-disclosure of their identity in any part of the study as well as keeping any shared information confidential (President of the Republic of South Africa, 2013). Knight (2019) argues that confidentiality and anonymity should not only be maintained during data collection but should also be maintained during data reporting. It is therefore important that an ethics application is submitted to an ethics committee before a study is conducted where the authorities will assess the proposed study ensuring that it will not bring harm to the participants.

Since this study involves human participants, an ethics application to conduct this study was submitted to the ethics committee of the University of the Witwatersrand. After ethical clearance was granted (see Appendix A), permission to engage with the teachers was requested from the Mpumalanga Department of Education. Permission to engage with the teachers was requested from the principals of the schools where these teachers are employed. The school's permission covered learners' participation in the study as they were indirectly involved. Copies of the permission letters sent to principals of the schools that participated in this study are shown in Appendix C. An approval letter from the Mpumalanga Department of Education is attached in Appendix B.

Once all the necessary permissions were granted, the purposefully selected novice teachers participating in the blended professional development intervention were invited to participate in this study and their written and signed consent was sought. The teachers were informed about the purpose of this study and how data will be collected to ensure that they provide informed consent to participate in the study. Since this study is linked to the intervention, teachers were informed that consent to participate in the intervention does not compel them to participate in this study as well. Hence, they were informed that participation is voluntary, and may withdraw their consent to participate in the study at any time, and that will not yield negative consequences or affect their participation in the intervention. They were also informed that the collected data will be stored safely in a password protected computer with restricted access to ensure that all information shared is kept confidential. In addition, their identities will not be disclosed in any part of the study. Teachers were not promised nor given incentives for participating in this study. Copies of the invitation letters and consent forms given to the teachers are shown in Appendix D and Appendix E, respectively.

5.7. DATA COLLECTION TECHNIQUES

To address the purpose of any study, one is required to select suitable techniques for collecting data. The techniques used to collect data for this study are summarised in Figure 12below. Figure 12 shows that data was collected mainly in two segments, before and after the intervention. In both segments, interviews and lesson observations were employed as methods of collecting data. Collecting the data in this manner, before and after the intervention, was useful in determining change, or lack thereof, in the teaching practice of the three novice Physical Sciences teachers who participated in this study and the blended professional development intervention. In addition to these interviews and lesson observation, field notes about important information regarding the intervention framework in relation to the teaching practice of the three novice teachers were noted. This was used to aid the researcher's understanding of its effectiveness in changing the teaching practice of the novice teachers with complex backgrounds.

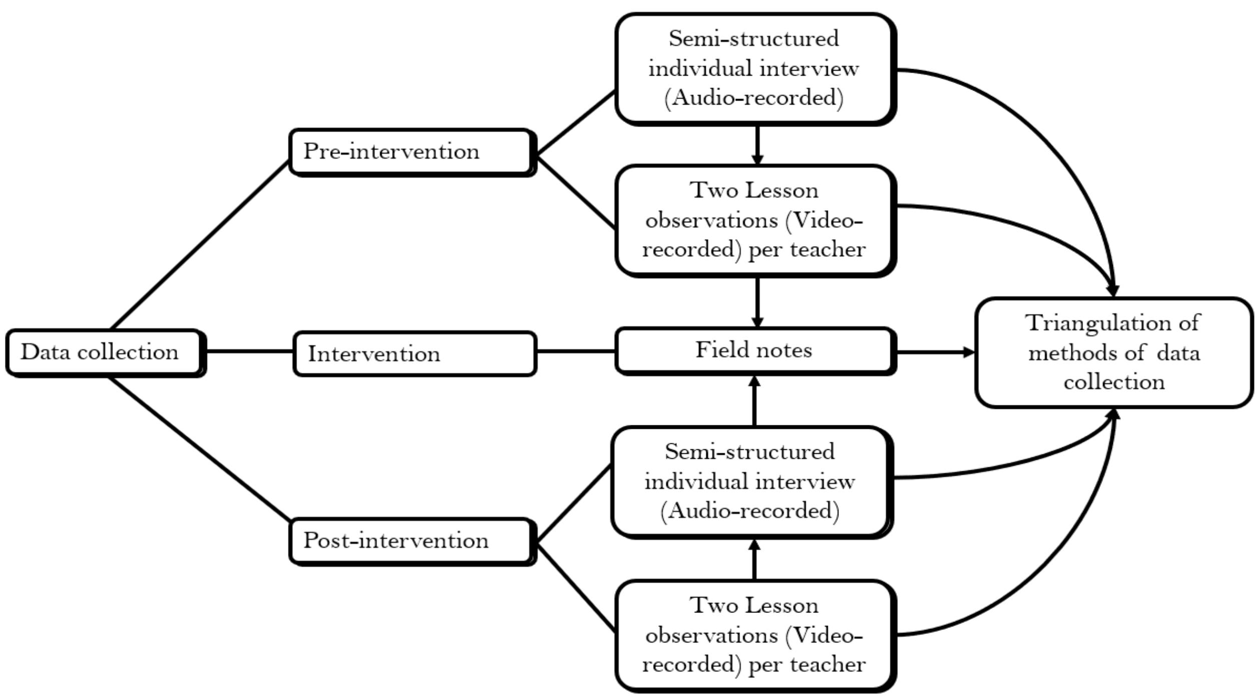


Figure 12: Summary of data collection techniques

Figure 12 above shows that semi-structured interviews were conducted first followed by lesson observations before the intervention and vice versa after the intervention. Starting with interviews before the intervention was important in helping the teachers familiarise themselves with the researcher, thereby giving them a better perspective of the study and what is expected of them. This sequence also helped the researcher in better understanding the needs of the teachers. The lesson observations were used to enhance the credibility of the interview responses. However, after the intervention, the researcher was focusing on determining changes in teaching practice, how the identified teaching and learning needs were addressed by the intervention and the views of the teachers regarding the blended approach adopted by the intervention. As such, lesson observations were conducted before the interview, allowing the researcher to ask questions that are based on (1) findings obtained from data collected before the intervention, (2) post-intervention lesson observations, and the (3) field notes taken during the intervention workshops. This sequence enhanced the quality of the collected data as findings of each data, e.g. interviews, were confirmed and enhanced by the other set of data, e.g. lesson observations.

Although using multiple methods to collect data was essential in addressing the purpose of this study, Figure 12 shows that these multiple methods of data collection were used for the purpose of triangulation. Triangulation is a process involving the use of two or more variables to come to an agreement or finding (Merriam & Tisdell, 2016). In research, these variables include (1) multiple theories to confirm emerging findings, (2) multiple researchers, (3) multiple sources of data, and (4) multiple methods of data collection (Merriam & Tisdell, 2016).

Triangulation of theories involves using two or more theories to make sense of the data and/or assess the accuracy and credibility of the collected data (Merriam & Tisdell, 2016). Researchers' triangulation involves the use of more than one researcher in collecting and analysing data (Merriam & Tisdell, 2016). In this type of triangulation, multiple researchers analyse the same data independently and compare findings (Patton, 2015, as cited in Merriam and Tisdell, 2016). Sources of data triangulation involve using consulting different sources of the data to support emerging findings. According to Merriam and Tisdell (2016), this type of triangulation takes into consideration the origin of the data, including space/context and time. For example, "comparing and cross-checking data collected through observations at different times or in different places, or an interview collected from people with different perspective or from follow-up interviews with the same people" (Merriam & Tisdell, 2016, p. 245). Data methods triangulation involve the use of multiple methods of data collection to examine research findings (Merriam & Tisdell, 2016). For example, this may involve examining the credibility of an interview response from the observed lessons, thereby triangulating between two methods of data collection - interviews and lessons observation.

Research shows that triangulation is one of the strategies that can be used to enhance the accuracy and credibility of the research findings (Cohen et al., 2011; Creswell & Creswell, 2018; Creswell & Poth, 2018; Merriam & Tisdell, 2016). As such, this study employed the triangulation of methods of data collection, whereby interviews and lesson observations conducted before and after the intervention as well as field notes taken during the intervention workshops to strengthen the credibility of the findings. According to Creswell and Poth (2018), the process of using any type of triangulation, and other strategies, to enhance the accuracy and credibility of the research findings is called validation. Chapter Six will present a detailed discussion of how validity was ensured in analysing the data to answer the four research questions of this study. The next sub-sections will describe in detail the methods of collecting data used for this study, as illustrated in Figure 12.

5.7.1. Semi-structured interviews

An interview is a dialogue between two or more people used to learn about the phenomenon of interest (Leavy, 2017). In this study, interviews with the teachers were conducted to understand, from their point of view, their needs and how well they have been addressed by the intervention, and how their teaching was before and how it has changed after participating in the blended professional development intervention. Thus, interviews with the teachers were conducted before and after participating in the blended professional development intervention. The pre-intervention interventions were used to answer the first research question. The post intervention interviews were conducted to answer the second and fourth research questions of this study.

The focus of the pre-intervention interviews was to explore the teacher's perspectives and practices in teaching Physical Sciences. The interview questions were aiming to understand the teachers' enjoyment and challenges in teaching the subject, their methods for connecting scientific concepts to real-world phenomena, and their use of analogies and representations. The interview questions before the intervention aimed to understand how teachers were integrating previous content knowledge, engaging learners, and addressing the varied meanings of scientific concepts. Finally, they sought to identify any desired changes in teaching methods and the teachers' goals for participating in professional development.

After the intervention, the focus of the interviews was to assess changes in the teachers' approach to teaching Physical Sciences, particularly after participating in a professional development intervention. The interviews explored how the teachers' methods for explaining scientific concepts, linking them to real-world phenomena, and using analogies have evolved. This also included any changes to the teacher's strategies for helping students understand complex concepts, integrating previous knowledge, and engaging learners. Finally, it was focused on identifying any new challenges experienced by the teachers and the achievements gained by participating in the intervention.

According to Leavy (2017), an interview may be unstructured, semi-structured and structured. Structured interviews offer no flexibility in terms of the questions to be asked during an interview as well as the sequence in which to ask them while unstructured interviews offer full flexibility (Cohen et al., 2011). In this study, semi-structured interviews were conducted with three novice Physical Sciences teachers as they do not restrict a researcher from pursuing interesting findings emerging from the interview (Merriam & Tisdell, 2016). Semi-structured interviews also give freedom in terms of the sequence in which questions are asked (Merriam & Tisdell, 2016). This type of interview, therefore, requires the researcher to have an interview schedule beforehand, consisting of a set of questions to be asked. The interview schedules used to collect data for this study before and after the intervention are shown in Appendix F and Appendix H, respectively. Transcripts of the interviews, to serve as examples, are shown in Appendix G and Appendix I.

The semi-structured interviews were conducted with individual teachers. This is because teachers were likely to be uncomfortable sharing their difficulties in the presence of their fellow colleagues. This ensured that the information shared with the researcher remained confidential and their identities remain unknown, thereby abiding by ethical protocols. As shown in Figure 12, the interviews were audio-recorded to ensure that teachers' responses were accurately captured. After each interview, the recordings were transferred into a password protected computer with restricted access in order to keep the information confidential. Table 11 below outlines the details of the data collected through semi-structured interviews with each novice Physical Sciences teacher.

Table 11: Data Collection information - Interviews

	Pre-intervention interviews		Post-intervention interviews	
	Date	**Duration**	**Date**	**Duration**
Mr Brown	22 June 2021	28: 24	29 October 2021	23:41
Mr Jones	23 June 2021	48:18	25 October 2021	35:17
Mr Smith	24 June 2021	43:06	29 October 2021	19:40

Table 11above shows that all the interviews with individual teachers before the intervention were collected in July 2021. The duration of the interviews was different for each teacher. This depended on the point of interest being raised by the teacher and followed upon by the researcher. Before the start of each interview, the teachers were reminded of their rights, for example, that they could choose not to be audio-recorded, not to answer the questions and withdraw their consent to participate in the study. The researcher also explained how the data will be used as well as how their identities will be protected during the data collection process and in the publications/writing.

5.7.2. Lesson Observations

In addition to semi-structured individual interviews, the teachers were followed into their respective classrooms where they were observed while teaching. Observation involves collecting data from social situations that are naturally occurring (Cohen et al., 2011). In the process of collecting data, as outlined by Cohen et al. (2011), there are different roles in which the researcher may opt to take. This includes being a non-participant observer detached from the research setting while making observations. In this study, the researcher took the non-participant observer role so to better understand the effectiveness of the blended professional development intervention on the teaching practices of novice teachers. The observed lessons were video recorded to capture all the moments during the lessons. Furthermore, teachers were given audio-recorders to complement the video recording in order to ensure the accuracy of the data. The dates and duration of each observed lessons are provided in Table 12 below.

Table 12: Data Collection information – Lesson Observations

	Pre-intervention Lesson observation			**Post-intervention Lesson observation**		
	Dates	**Lesson 1 Duration**	**Lesson 2 Duration**	**Dates**	**Lesson 1 Duration**	**Lesson 2 Duration**
Mr Brown	23 and 28 June 2021	01:34:16	36:11	25 and 29 October 2021	53:52	51:00
Mr Jones	24 and 26 June 2021	45:43	01:12:59	25 and 29 October 2021	54:45	67:21
Mr Smith	24 June and 16 July 2021	41:49	30:09	25 and 26 October 2021	71:49	50:40

Table 12 above shows the duration of each observed lesson before and after the intervention. Table 13 below shows the topic taught by each teacher during lesson observations. It is important to note that these teachers were allowed to teach any topic they preferred. This was, firstly, to avoid disrupting the teaching plans of these teachers since they were involved with Grade 12 learners, a high priority grade in the country. This grade was chosen because the intervention focused only on topics of this grade. Secondly, this was to determine the extent in which these teachers could apply the acquired knowledge from the intervention workshops to other topics of the subject. Table 13 below shows the topics of each observed lesson per teacher.

Table 13 shows that Mr Brown taught Rates of Reaction, a Chemistry topic, in all his observed lessons before the intervention. The first lesson focused on factors affecting the rate of reaction while the second lesson focused on the mechanism of reaction and catalysis which involves interpretation of graphs. Post intervention, Mr Brown was observed teaching Physics topics to his Grade 12 learners. The first lesson was on Electric Circuits and the second lesson was on Newton's Laws. Both lessons after the intervention were based more on calculations, as such, no new concepts were introduced.

Table 13: Topics taught per observed lesson

	Pre-intervention Lesson observation		**Post-intervention Lesson observation**	
	Lesson 1	**Lesson 2**	**Lesson 1**	**Lesson 2**
Mr Brown	Rates of reaction: Factors affecting rate	Rates of reaction: Mechanism of reaction and of catalysis	Electric Circuits	Newton's Laws
Mr Jones	Acids and bases (acid and base models, weak and strong acids and bases, conjugate acid-base pairs, water ionisation, pH scale)	Acids and bases (pH calculations)	Chemical equilibrium	Organic Chemistry
Mr Smith	Momentum	Electric Circuits	Photoelectric effect	Doppler effect

Table 13 shows that Mr Jones taught Chemistry topics on all his observed lessons. Before the intervention, all the Chemistry topics were based on Acids and Bases. However, the first lesson was introducing learners to this topic, hence it addressed acid and base models, weak and strong acids and bases, conjugate acid-base pairs, water ionisation, and basics of pH scale. The second lesson, before the intervention, continued from the pH scale concept to calculations. After the intervention, Mr Jones' first and second lessons focused on Chemical equilibrium and Organic Chemistry, respectively.

Mr Smith taught Physics topics on all his observed lessons. They were all new topics. During the first, lesson before the intervention, Mr Smith taught Momentum followed by Electric Circuits in the second lesson. After the intervention, Mr Smith taught Photoelectric and Doppler effects during the first and second lessons, respectively.

Before each segment of data collection, the teacher and their learners were reminded of the purpose of the study. This was important for the learners as their natural learning was disturbed by the presence of the researcher who was recording their lesson. This explanation ensured that learners were at ease knowing that the focus of the study was not on them, and that the information was to be kept confidential. Hence, during the lesson observations, the teacher was not recorded when called upon by a learner for a one-on-one interaction. This was to respect the privacy of the learner. This included the segments of the recordings captured by the audio-recorder carried by the teacher during the one-on-one interaction. After each lesson observation was recorded, the data was transferred into a password protected computer to ensure that it remains confidential. Transcripts of the lesson observations are shown in Appendix K and Appendix L.

5.7.3. Field Notes

Figure 12 shows that, in addition to the semi-structured interviews and lesson observations, field notes were taken during the intervention workshops. These field notes were taken to note down the framework of the interventions as it is a significant part of this study. These notes included, amongst other interesting aspects, (1) the attendance of the teachers who participated in this study, (2) the topics addressed during workshops and duration, (3) ideas shared about the teaching and learning of the addressed topics, and (4) active participation of the novice teachers in these workshops. These field notes were useful in understanding the views of the teachers with regards to the blended approach adopted by the intervention to professionally develop them in teaching Physical Sciences. As mentioned earlier, ethical protocol was followed in ensuring that the field notes only focused on the activities of the intervention workshop as well as the activities of these three novice teachers. A sample of the field notes written in one of the workshops is shown in Appendix M.

5.8. OVERVIEW OF THE ROLES OF THE INTERVENTION ORGANISERS

This intervention consisted of two facilitators. The first facilitator, Dr Adams, is a lecturer in a tertiary education institution in South Africa with several years of experience teaching Physical Sciences. The second facilitator was Dr Davis who has been a Physical Sciences subject advisor in one of the districts of the Gauteng province for fourteen years. She has also taught Physical Sciences for ten years in the Mpumalanga and Gauteng provinces. Dr Davis and Dr Adams work at the same institution.. During the intervention workshops, Dr Davis was the main facilitator, and facilitated all the workshops. Dr Adams half-facilitated only one workshop, on Electrodynamics, and spent the rest of the time during the intervention supporting Dr Davis. Dr Davis was responsible for the overall coordination of the intervention workshop which included the selection of workshop topics; teacher activities; developing slides and facilitating the workshops. Dr Adams was overseeing the whole study – the research project including the intervention.

Dr Baker was responsible for designing the revision material for the learners. Dr Baker has more than ten years of experience teaching Physical Sciences at school level. Dr Baker, however, did not take part in the workshops. The intervention had two research assistants, the researcher of this study and Mr Tailor. The roles of both researchers were limited to general caretaking as well as the administration activities of the intervention, especially the booking of data collection resources. As such, they were not involved in the planning and implementation of the intervention activities. These research assistants took on this passive role due to their limited experience in teaching and teacher development. Detailed information on the role played by the researcher of this study is outlined below.

5.9. ROLE OF THE RESEARCHER IN THE INTERVENTION

As mentioned previously, the validity of the research findings can be improved by the use of triangulation, which is the process of using more than one variable to obtain a finding (Merriam & Tisdell, 2016). Other than triangulation, there are other strategies that can be used to strengthen the validity of research findings. This includes the disclosure of researcher's biases, values, and past experiences (Creswell & Poth, 2018). This disclosure outlines and clarifies "the bias the researcher brings to the study" (Creswell & Creswell, 2018, p. 200). Therefore, the next paragraphs disclose the role of this researcher in the blended professional development intervention as another strategy to further enhance the validity of this study's findings.

The role of the researcher in the blended professional development intervention was that of an administrator. The researcher was responsible for all the administrative duties of the project. Part of this involved participating in all strategic meetings with the members of the project, including officials from the Mpumalanga department of Education and University of the Witwatersrand. As an administrator, the researcher was responsible for organising all the workshops with the teachers, both virtual and physical workshops, ensuring that they proceeded smoothly. Furthermore, the researcher was present during the workshops, recording the workshops, providing refreshments that were paid for by the intervention organisers to both facilitators of the workshops and teachers. However, none of the workshops were presented by researcher, although she participated in meetings, as the intervention administrator, where the content of each workshop was shared with the rest of the intervention organisers.

The role of the researcher in intervention may have influenced how this study's participants responded in the data collected post intervention. They may have seen the researcher as one of the intervention core organisers, therefore making it difficult for them to honestly share their views about the affordances and short comings of the intervention in addressing their concerns. However, the effect of this risk was reduced by the use of a triangulation of data methods, where teachers' responses were not taken as they are. Instead, evidence to support or counter support their responses was sought from the lesson observations and field notes. This must have improved the validity of the findings of this study.

The researcher was also able to write field notes of the intervention workshops, from which access to the workshops was provided by her administrative role in the intervention. These field notes emanate from information gathered through the attendance registers of the intervention workshops as well as video recordings of both online and face-to-face workshops. However, ethical protocols were observed whenever the researcher was exposed to such information.

The researcher acknowledges that her administrative role in the intervention enhanced her familiarity with the teachers as well as the content of each workshop. The researcher employed the triangulation process when analysing the data to prevent her knowledge of teachers and role in the intervention from influencing the findings of this study. The details of the type of triangulation followed in answering each research question of this study are discussed in detail in the following chapter, Chapter Six.

5.10. SUMMARY OF THE CHAPTER

This chapter has outlined that this study follows the multiple cases design, using the qualitative approach to study the effectiveness of the blended professional development intervention in the teaching practices of novice Physical Sciences teachers in rural schools of the Mpumalanga province. Three teachers participated in this study and were selected using the purposive sampling method. All three teachers were novices in the teaching of Physical Sciences to Grade 12 learners. To collect data, two video recorded lesson observations and individual interviews were conducted with each teacher before they participated in the blended professional development intervention. Two more video recorded lesson observations and individual interviews were conducted with each teacher after they participated in the blended professional development intervention. Furthermore, field notes were written during the intervention workshops. These three methods of collecting data were used to strengthen the validity (accuracy and credibility) of the findings of this study through the triangulation process.

In addition to triangulation of data methods, this chapter has described the role of the researcher in the intervention and how this may have influenced the participants' behaviour during the collection of post-intervention data. This disclosure included a description of how the role of the researcher in the intervention gave her access to additional data she, otherwise, would not have access to, such as the attendance registers of the participants, used to generate and confirm some content of the field notes. In addition, the researcher has elaborated on how her involvement in the intervention may have influenced her interpretation of the data. These disclosures represent another strategy, besides triangulation, used to strengthen the validity of the findings of this study. The next chapter outlines the process followed in analysing the data to answer each of the research questions of this study.

CHAPTER SIX: DATA ANALYSIS

6.1. INTRODUCTION

The purpose of this study was to determine the effectiveness of a blended professional development intervention on the teaching practices of novice Physical Sciences teachers in rural schools of Mpumalanga province. Three teachers, with less than five years of experience in teaching Physical Sciences at Grade 12 level, participated in this study. Each teacher was interviewed individually and two of his lessons on preferred topics were observed before and after they participated in the intervention. To support some findings from the interviews and lesson observations, filed notes were taken during the intervention. These field notes were based on activities that concerned the novice teachers in relation to the purpose of this study. This chapter outlines the processes followed in analysing the collected data to address the purpose of this study. This includes a description of processes followed to ensure credibility during the data analysis process.

6.2. DATA ANALYSIS PROCESS

Analysing qualitative data is a process that involves several sequential steps that are necessary in interpreting meaning from the collected data (Creswell & Creswell, 2018). According to Creswell and Creswell (2018), the first step in analysing the data is to organize the data and prepare it for analysis. This process involves "transcribing interviews, optically scanning material, typing up field notes, cataloguing all of the visual material, and sorting and arranging the data into different types depending on the sources of information" (Creswell & Creswell, 2018, p. 193). In this study, the interviews and recorded lesson observations conducted before and after the intervention were transcribed. A total of six interviews and twelve classroom observations were transcribed. The field notes, including attendance registers from the intervention workshops, were typed neatly and stored safely for use as additional sources of data to provide evidence that supports generated meanings. The following section outlines the step by step processes followed by the researcher in analysing the data to answer the first research question of this study.

6.2.1. Teaching and learning needs of the novice teachers

The first research question of this study intended to understand the teaching and learning needs of the novice Physical Sciences teachers. The data analysis process to address this research question involved reading through all the data. By reading through all the data, as posited by Creswell and Creswell (2018),the researcher attains a general sense of the meanings emerging from the data. They add that researchers may add notes on the transcripts while reading through all the data (Creswell & Creswell, 2018). According to Merriam and Tisdell (2016), the process of making annotations while reading through the data is called coding. Coding is a "process of organising the data by bracketing chunks (or text or image segments) and writing a word representing a category in the margins" (Creswell & Creswell, 2018, p. 193). The annotations made on the transcripts during open coding are called codes, "a name or label that the researcher gives to a piece of text that contains an idea or piece of information" (Cohen et al., 2011, p. 559). Thereafter, a coding framework/book was developed consisting of themes and sub-themes adopted from Mushayikwa and Mushaikwa (2023) because they were derived from a large sample size, and therefore reliable more than the ones that may be generated from this study's small sample size. The coding framework consists of operational descriptions of each sub-theme as shown in Table 14below.

Table 14: Themes of novice teachers' needs (adopted from Mushayikwa &Mushaikwa (2023))

Classroom Efficacy	
Sub-theme	**Description**
Comprehension	Understanding of content knowledge for the subject, including language barriers related to the subject content
Content representation	Identifying big ideas, explanation, and analogies, including examples from everyday life
Instructional selection	Teaching and learning strategies and pedagogical resources
Adaptation of content to learners' needs and level	Identifying misconceptions, and concepts that are difficult to understand by the learners in a topic.

Professional Efficacy	
Classroom management	Use of time, pacing, planning, and discipline
Identity development	Motivation and attitude towards learners and the subject
Professional integrity	Ethics and attitude towards the profession

Table 14 above shows that the teaching and learning needs of these teachers were analysed using the concept of teacher efficacy, which determines the extent to which teachers will professionally develop themselves to improve their teaching practice and the performance of their learners (Mushayikwa & Lubben, 2009). As such, sub-themes of classroom efficacy and professional efficacy from Mushayikwa and Mushaikwa (2023), as shown in Table 14 above, were adopted and used to categorise the data collected from interviews. Under classroom efficacy, the needs of the teachers were classified into four sub-themes – comprehension of the subject content knowledge; content representation; instructional selection; and adaptation of content to learners' needs and level. Under professional efficacy, the needs of the teachers were classified into three sub-themes – classroom management; identity development; and professional integrity. Administration, a category under professional efficacy, as identified from Mushayikwa and Mushaikwa (2023) was excluded from this study because it falls beyond the scope of this study. Table 15below presents examples of segmented data for each sub-theme as per their descriptions in Table 14 above.

Table 15: Examples of each sub-theme of novice teachers' needs

Classroom Efficacy	
Sub-theme	**Example from data**
Comprehension	***Mr Smith:*** *It's just that our learners need to be taught those Physical Sciences jargon. Ja, that's where they confuse…what do you call it…each subject has its own language. Ja, so if learners can be taught from the early stages, I think they can get better results.*

Content Representation	***Mr Brown:*** *Okay, for physics, you know it's more practical, so to make examples or these analogies, it's easy. But for chemistry, you just to make them there and there, where you see that okay, this one is simple. I try to make a way around. But some of the things, chemistry is more microscopic.*
Instructional selection	***Mr Brown:*** *Eish, the way I'm teaching, it's more…okay, it's more teacher centred. I do more most work, okay the learners do work but I do most work by passing information that I know to them. But if ever maybe it can be more practical, so that maybe if ever there's something to do, they do it on their own practically before maybe I give them information, I think that would be better*
Adaptation of content to learners' needs and level	***Mr Smith:*** *And what is worse, each year we have a different group of learners. So, when we say, why last year we performed better, this year, forgetting these learners their basic skills are different. Their knowledge gaps. At one stage some were good, come the following year, hey! Very slow learners, very slow. In a…like a chapter needs four hours…and I spend two weeks. So that's the problem. You can relate this thing…if you check those model C schools, they don't have the so-called extra classes, weekends and what-what, Sundays camps. What's wrong with us? You come in the normal teaching hours, you go after school, you come weekends. So, you can see there's a problem. There's a problem. Sometimes I may ask, is it because this subject is offered in English? Some will say, haai, no! Some will say, it's just that we are not serious.*
Professional Efficacy	
Classroom management	***Mr Brown:*** *I don't know…I'm always behind. I'm always…eish, I cannot leave someone not understanding. I cannot move on if someone doesn't understand.*
Identity development	***Mr Jones:*** *Physics, it's more of my favourite since I teach maths. And then with chemistry, there are times where I feel like I'm*

	doing this because I have to. But it's not something that I enjoy doing. But now…okay, that feeling was there before, like 2018/2019 that feeling was there. But now, I have come to equalize these things to say, no, it's fine, since we calculate both sides, but when it comes to… you know teaching, it has marking. For marking I go for paper one because I enjoy maths. I enjoy physics than chemistry. But I do teach chemistry since I'm the only teacher who's responsible for both, chemistry, and physics.
Professional integrity	***Mr Smith:*** *Though what we usually encounter, you find that a teacher…well it's normal, you specialised in physics, strictly physics, and then somebody specialised in chemistry, and when you come to the field here, they say you are a science teacher but your specialisation it's one-sided. So that's why we'll find that maybe you are strong in paper one. At some stage you don't have an interest in chemistry. That's where problems start to emanate. But what was worse, this thing of saying this teacher is good in paper one, he will make sure he only teaches paper one the whole year.*

Table 15 above provides examples of each sub-theme of classroom and professional efficacy from data collected from interviews collected before the teachers participated in the intervention. After operational descriptions of the sub-themes were developed as illustrated in Table 14 and Table 15 above, relevant codes were assigned to all data segments corresponding to each pre-determined theme and sub-theme. Thereafter, the coded data segments were organised into groups according to their respective themes and sub-themes as shown in the picture below.

Classroom Efficacy - Comprehension of Content		
Mr Brown	**Mr Jones**	**Mr Smith**
how do you work your way around that? To make sure that at the end of the day they understand that a concept is not just a concept standing on its own, it has this concept that it can talk to? Oh, any other example. Okay, let's take maybe power. Power is a rate at which work is done. Power is a big word, there is work, and there is rate. So, what I do is, I don't just go straight to power, I start on work done, define it so that they know what is work done. Then from there, I derive up until I get to power. So that every concept behind power they understand and then be able to apply it, you see. What I do is I start from the beginning.	Alright, with that…with this subject, I think we are lucky, because mathematically we call them collinear, they join each other. If you can check, you cannot start teaching work-energy and power without teaching Newton's law. Because Newton's law is interlinked with what? Work-energy and power, but you must do what? Newton's law first. Meaning, automatically the subject itself it's interlinked. You don't have to stress yourself. Because they will ask you a question in, let's say for example, in question seven, electrostatics, they will ask you a question of what? Of momentum in question four. And you will be able to answer what in that question. That is why we don't leave what we have done before, we go with it everywhere we go, until the last topic.	It's just that our learners need to be taught those physical science jargon. Ja, that's where they confuse…what do you call it…each subject has its own language. Ja, so if learners can be taught from the early stages, I think they can get better results.
If you are powerful it means you are hardworking. What you do, you do it better. And if you have greater power it means you do a lot of work in a small period of time. I try to link those two. Because a powerful person will take a community to go get vaccinated. And a person who has more power will take the same people to go get more vaccine at a shorter time. I try to relate the two. Because a powerful person has power because he does more work at a short period of time. A person who is not powerful we know is lazy.	Work let's say for example. When we say work, we go to work, but in physics it's different there. We want to know the work done by friction, what is the work done by whatever? But with such examples it's tricky because you must explain. That's where you take them out of their real world, and then you bring them to physical sciences, that in the real world, yes, power may refer to whatever thing that you know, and you're used to. But in this case, when we see power, we are referring to what? Power that we see through what? Energy being transferred. You understand? And how is the energy transferred? We check the time. And then how do we see the power? For example, if we can check electricity, electricity flows, and then for us to determine the power, we must have a light bulb. A light bulb it's a hundred watts. It means the power that the light can brighten, or the energy that it can take, it means it can be that of hundred watts. When we say power, we're not referring to that strength whereby you can just lift twenty people at once. We try to take them out of that knowledge, that now we are no longer dealing with this. You must now know that work is energy. Energy is energy. Energy and work they are correlated. That's why the unit for work is joules. And the unit for energy is joules. These two means one thing. When we say work and	If time allows, I think it's advisable if you say, you are approaching a topic, find those words that would be often used. And then compare with the general usage in the public space. In general people will use this word, but the meaning, when we are in this subject, it's different. For example, we talk of concentration. This learner doesn't concentrate. But in physics we don't talk of such, we are meaning the amount of…is it too much or is it less? Things like that. So we must have those key words that we explain in advance. So that when you teach the learner must not confuse that word with the word he or she encountered in the English lesson. In geography or…because each subject has its own jargon. So the learner must be vigilant with such words. And the only way to do that is when you introduce those words to the learner, that, oh, here when you use this word, when you say it's momentum, even the formula will tell you, if you are mathematically inclined, the formula will tell you, oh, here, you see you're multiplying a mass. It's a product. It's a product of mass and velocity. You are not talking of those momentum outside where they will say, haai! it's like you are gaining momentum it's like, ja, they are coming in full force! You see, things like that. And so they must differentiate such

Picture 1: Categorising data segments into relevant themes and sub-themes

After categorising the transcribed data into the relevant themes and sub-themes, the segments of data per category were interpreted. The interpretation of the categorised data involved generating meanings. For every generated meaning per category, evidence to support it was sought from the other collected data sets, field notes and lesson observations. According to Merriam and Tisdell (2016), this process of using multiple data sets to provide supporting evidence to the findings of a study is called triangulation of methods of data. Triangulation is used to enhance the validity of the findings by strengthening their accuracy and credibility (Creswell & Poth, 2018). An example of this process, as followed in this study, is outlined in Figure 13 below.

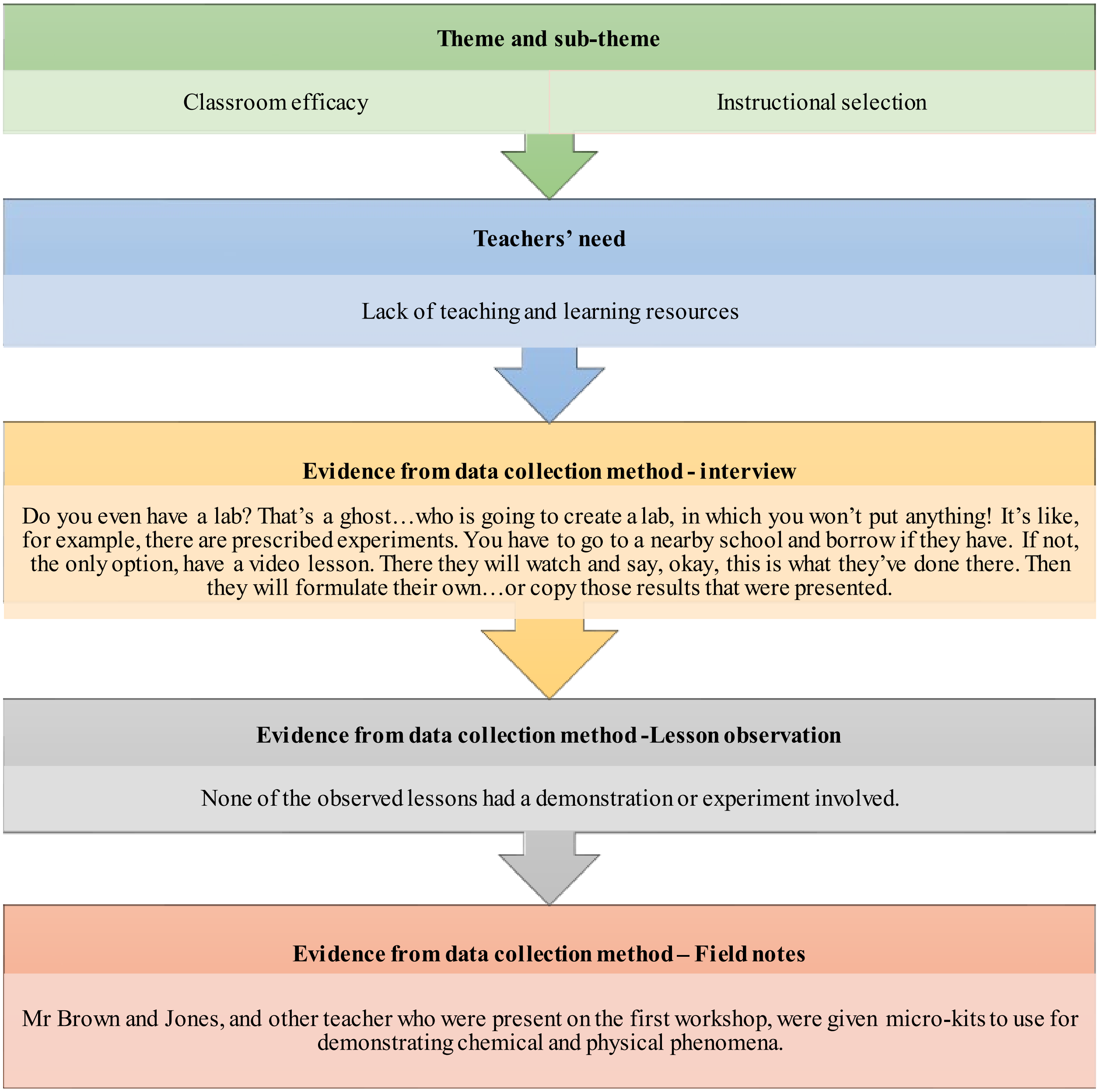


Figure 13: Example of data methods triangulation

Figure 13 above shows that teachers lack teaching and learning resources. Evidence of this need is found in an interview extract where Mr Smith explained that their schools do not have a science laboratory to conduct experiments. The extract from the interview data further explains that the teachers’ tens to borrow material to complete prescribed experiments from nearby schools. Otherwise, they watch videos of experiments to complete the requirements of the prescribed experiments. Figure 13 above shows that evidence of this need was sought from lesson observations. However, there was no evidence as all observed lessons did not involve either videos of experiments or demonstrations where the teacher would use laboratory material to aid learners' understanding of a concept or scientific phenomenon. It was evident from field notes that all the teachers, except for Mr Smith who was absent from the first workshop, were given micro-kits by the intervention organisers that they could use to demonstrate chemical and physical phenomenon, aiding learners' understanding.

Although the teaching and learning needs of the teachers were determined mainly from the data collected before they attended the intervention, data collected after the intervention was also utilised. This is because some of the teaching and learning needs were not apparent until after the intervention and with close comparison between the two data segments. As a result, in addition to data methods triangulation, data sources triangulation was also used. As discussed in Section 5.7 of Chapter Five, data sources triangulation considers the origin of the data, including space/context and time (Merriam & Tisdell, 2016). This process is illustrated in Figure 13 above where evidence from field notes written about the intervention was used. The evidence from the field notes represents a different data source in terms of the time in which the data was collected during the intervention workshops.

In terms of context, the roles of the teachers were reversed during the intervention workshops as they acted as learners being 'taught' by the facilitator (as per the characteristics of the training model illustrated in Table 2 and adopted in this study as shown in Figure 10). As such, although the example above represents a triangulation of methods of collecting data, it also acts as an example of data sources triangulation, similar to the data collected before and after the intervention. Therefore, both data sources and data methods triangulation were used to enhance the validity of this study's findings.

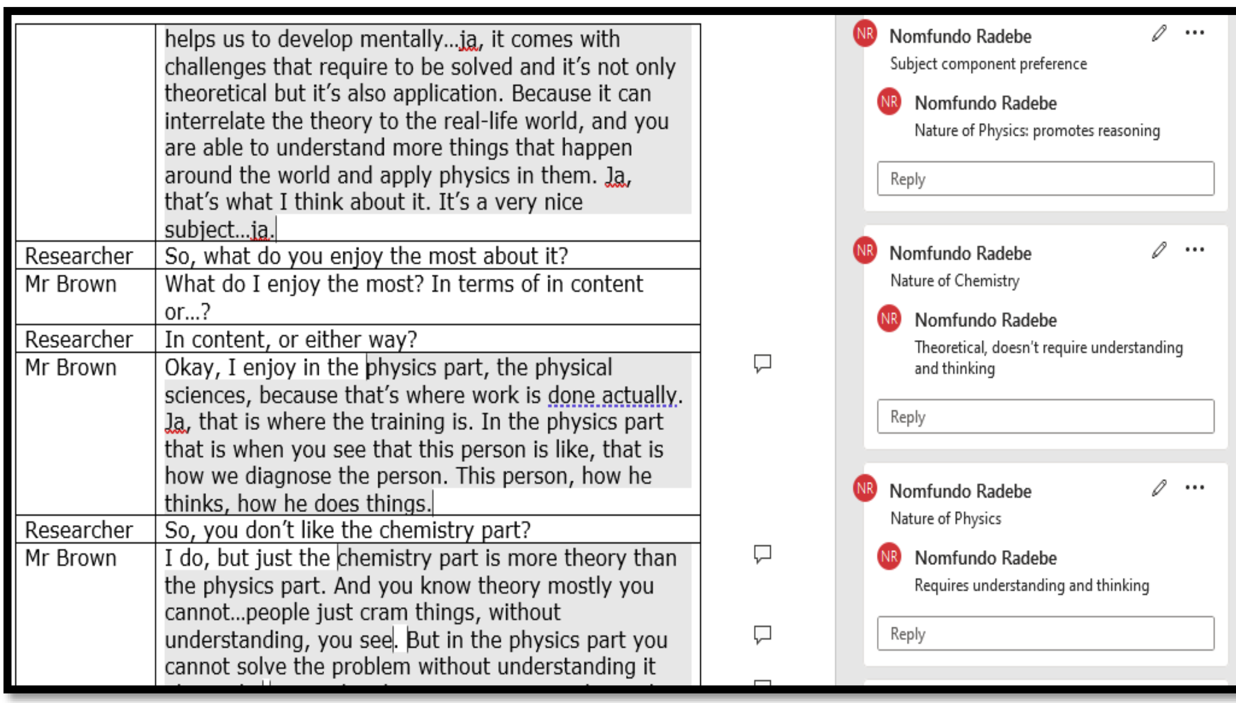
In addition to improving the validity of this study's findings, the triangulation of data sources and data collection methods enhanced the reliability of the findings. Reliability refers to the extent in which the same findings will be obtained if the same study was to be repeated or the data was re-analysed (Merriam & Tisdell, 2016). It is about the consistency of the research findings with the collected data (Merriam & Tisdell, 2016). Therefore, by using multiple sources of data collection methods and data sources, the consistency and reliability of the findings was enhanced.

In addition to using multiple data collection methods and data sources triangulation to enhance reliability, the analysis process was not linear as presented above. The steps outlined above had to be repeated several times to ensure consistency. This repetition was mostly necessitated by segments of the data that could fit in more than one theme and/or sub-theme. This required the researcher to (1) revisit the descriptions of each theme and sub-theme, (2) critically analyse the data to determine characteristics that make the data segment suitable for each possible theme and/or sub-theme, and (3) determine the value added by the data segment in each possible theme and/or sub-theme. Using these three steps, the researcher could decide whether the data segment can fit in more than one theme and/or sub-theme and place it accordingly, in one or more sub-themes. The data was revisited and cross-checked multiple times to ensure that the data segments were in the relevant theme and/or sub-themes and provided meaning which resonated with the theme/sub-theme description. Therefore, through this repeated analysis of the data, in addition to data sources and data collection methods triangulation, the validity and reliability of the findings was enhanced.

Creswell and Poth (2018) add that providing in-depth descriptions of the participants or setting under study is significant as it enables the reviewers to judge the transferability of the findings to other settings. In this study, detailed descriptions of each case are provided in Table 10. In this study, these descriptions are useful in understanding the unique needs each of these cases have and how these needs relate to their educational backgrounds. These descriptions enhanced the validity and reliability of the findings of the first research question of this study. The findings derived from the data analysis process outlined above are presented in Chapter Seven. The next section outlines the process followed in analysing the data to answer the second research question of this study.

6.2.2. Effectiveness of the blended workshops - views of the novice teachers

The second research question of this study intended to determine the effectiveness of the blended workshops from the views of the teachers. Thus, after the data was organised and prepared for analysis, the next step was to read through all the data to attain a general sense of the meanings emerging from the data while coding on the transcript margin (Creswell & Creswell, 2018). At this stage in the data analysis process, Merriam and Tisdell (2016) posit that the coding process is open because the researcher is open to any ideas. The coding process that was followed in this study is shown in Picture 2 below.



Picture 2 : Open coding exemplar

Picture 2 above shows that the researcher read through all the interview transcripts of data collected before the intervention per case. While reading, notes (also known as codes) were made on the margin/right hand side of the transcript. These notes represent emerging meanings and general thoughts the researcher had while reading each case transcript, as illustrated in the picture below. These annotations were guided by the researcher's understanding of the purpose of the study as well as the research question the study intended to answer. After reading and open coding all the interview transcripts of data collected before the intervention, we went on to read and open code the interview transcripts of data collected after the intervention.

After open coding all the interview transcripts, the next step during data analysis was axial coding. Axial coding is a process whereby codes that seem to go together are grouped together and their meaning is sought (Merriam & Tisdell, 2016). The meanings that emerged from interpreting the codes grouped together during axial coding are known as categories or themes. In this study, after all the codes that seem to go together were grouped, four categories/themes emerged – attendance; flexibility; individual support; and engagement. The description of each category is provided in Table 16below.

Table 16: Themes and descriptions - views of the teachers about blended intervention workshops

Theme	Description
Attendance in online and face-to-face workshops	Challenges hindering attendance in these blended workshops.
Flexibility in online and face-to-face workshops	Affordances of blended workshops
Individual support in online and face-to-face workshops	Available support to individual teachers in blended workshops.
Engagement in online and face-to-face workshops	Teachers' active engagement in blended workshops

The table above shows that the effectiveness of the blended intervention workshops can be defined in terms of attendance; flexibility; individual support and engagement. In terms of attendance, the attendance of the teachers in online and face-to-face workshops is compared. Thereafter, challenges hindering attendance in anyone of these types of workshops are discussed. Flexibility examines and present the advantages of online and face-to-face workshops as voiced out by the teachers during the interviews. Opportunities of individual support made available to teachers in online and face-to-face workshops were compared. Table 17 below provides examples from data of each category/theme.

Table 17: Examples from data - views of teachers about blended intervention workshops

Theme	**Examples from data**
Attendance in online and face-to-face workshops	***Mr Brown:*** *For those workshops that are online, data is expensive. If you request the school to help you with data, they say no or promise to assist but they never do. There was this one time where I attended half of the session, because I received a text stating that I have used 50% of the data.* ***Mr Brown:*** *I had to go attend physical workshops with my own money, If I mention here at school that Institution X people want us to meet physically at School D. They won't give me money to go there. I expected the department or my school to support me financially so that I can attend. If ever they give me money to go attend, I will be owing it to them to be there. But if I am using my own money, I can decide not to waste my money to go there, and I won't go.*
Flexibility in online and face-to-face workshops	***Mr Smith:*** *With the online one, you can attend with your learners. You can project it there and they listen together. But with that one that requires the teacher to rush in there, you may find that he rushes in there but when he comes*

	back, some of the things won't be delivered the same way they were delivered that side.
Individual support in online and face-to-face workshops	***Mr Smith:*** *Personal interaction is also important because with this online thing [online workshops], one might be busy with something else this side. They may be watching but they won't participate fully. But if sometimes we do a physical one [face-to-face workshop], we get to see people, you share your concerns directly to the right person.*
Engagement in online and face-to-face workshops	***Mr Brown:*** *The online one, I'm alone, you do not see me, you only see any of the screen that you project there. In most case, I would be busy with my things putting the phone down. The was a day when they asked me a question, I was not even there. I was called saying they are looking for me. I was busy with my things. So, I lose concentration quicky with online workshops because I'm in my space and if am in my space I might even sleep.*

The abovementioned examples have been drawn from the interviews collected after the teachers participated in the intervention. The axial coding was followed by the segmentation of the data under each theme, as illustrated Picture 3below.

Theme	Teachers views regarding the effectiveness of the blended workshops		
	Mr Brown	Mr Jones	Mr Smith
Attendance	For those workshops that are online, data is expensive. If you request the school to help you with data, they say no or promise to assist but they never do. There was this one time where I attended half of the session, because I received a text stating that I have used 50% of the data. Yes, this is for me but its also for the school . But the physical workshop, I do not mind attending them. I had to go attend physical workshops with my own money, If I mention here at school that Wits people want us to meet physically at Bunny Khosa. They won't give me money to go there. I expected the department or my school to support me financially so that I can attend. If ever they give me money to go attend, I will be owing it to them to be there. But if I am using my own money, I can decided not to waste my money to go there, and I won't go.	Yeah, you know the online...It does help but I think we have more challenges than when we are doing it physical. So, the only challenge with online, you know online we'll be experiencing maybe network problem. You know. I remember there was one which I couldn't even log in because of network. I remember I was not around; I was on a workshop and at the place my network was not supported, I am using Telkom. So if I'll be having a challenge of network, it means I won't be able to attend, but when it comes to physical, with or without network, with or without electricity, you see the person and they will be like yeah .	The intervention is helpful, its developmental. The other issues you could be data problem. Sometimes, like the online one, you must have enough data to listen and participate, all of that. So you might find that some teachers might be logged in now for 10-15 minutes, then he's out, just like that. I don't know how, but if there was some sponsors somehow that could help supplement a little in terms of data, that could be another issue. Yeah.
Flexibility		With physical, the only challenge is that even if you want to attend with your learners, you can't because the space will be limited . But online I can attend with my learners. I can use a projector; we sit down and they also listen at the same time . They both work, depending on the challenges that we face when we are attending them because with the physical I cannot attend with my learners. But for me to benefit the learners, I need the virtual one but at the same time I must be in a place where I am covered by signals otherwise I can't. Like I remember we were doing, was it rate of reaction? I don't know. That one was very useful. I was able to connect here and then they were listening. Yeah, they filled this place. They were watching here and if we are busy asking questions, they were listening. I was asking questions as a learner, they were also listening and benefiting, taking notes.	They are both helpful. I cannot say that this one was poor compared to the other one was because with the online one, you can even do with your learners. You can project it there and they listen together . But with that one that requires the teacher to rush in there, you may find that he rushes in there but when he comes back, some of the things won't be delivered the same way they were delivered that side. But both techniques are good
Individual support			Yah, they are good. Personal interaction is also important because with this online thing, one might be busy with something else this side. They may be watching but they won't participate fully. But if sometimes we do physical one, we get to see people, you share your concerns directly to the right person.
	Let me tell you why the online one doesn't work better. The online one, I'm alone, you do not see me, you only see any of the screen that you project there. In most case, I would be busy with my things putting the phone down. The was a day when they asked me a question, I was		

Picture 3: Segmentation of data

The last step undertaken in analysing the data was to interpret meaning from the segmented data per theme. The interpretation of this data was focused on understanding the views of the teachers about the effectiveness of the blended professional development intervention. This included an understanding of the views of the teachers regarding the intervention workshops, whereby some workshops were online while others were face-to-face. The analysis focused mainly on the interview data and used field notes to provide supporting evidence, as illustrated in Figure 14 below.

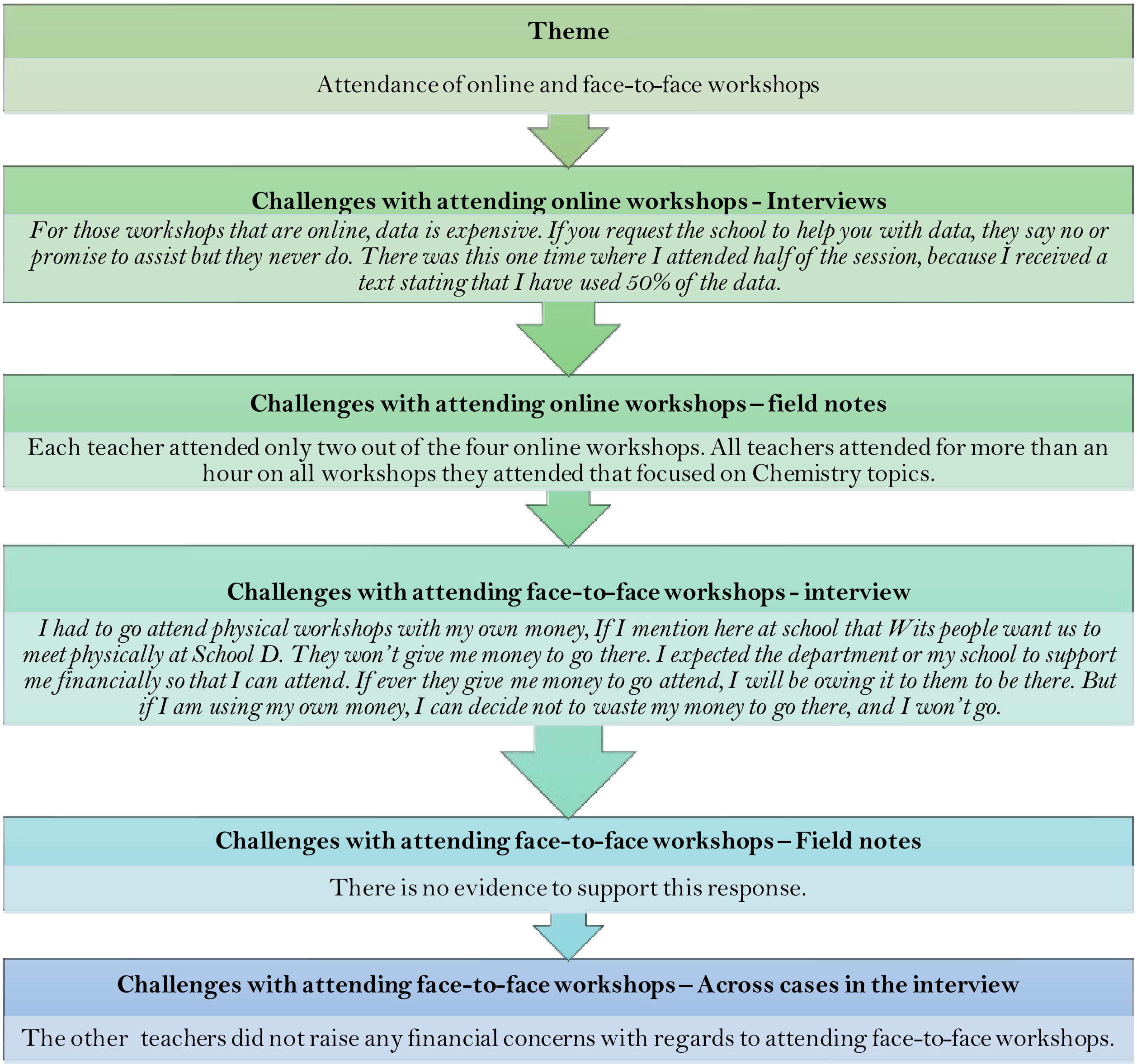


Figure 14: Data sources triangulation example

Figure 14 above shows how triangulation of sources of data was used to determine the effectiveness of the blended intervention workshops. The nature of the second research question demanded that views of the teachers be considered. As such, the findings of this study are drawn mainly from interviews collected after the intervention and supported by field notes, as shown in Figure 14 above. Figure 14 shows that the teacher, whose response is illustrated above, had a challenge attending online workshops due to expensive internet data. This observation came out in the field notes too, based on attendance registers, which describe the number of online workshops the teachers attended and the amount of time they spent on the online workshops they attended.

Figure 14 above shows that the teacher's attendance in face-to-face workshops was hindered by lack of financial support from the school. This is despite the fact that was no evidence or corresponding response from the other teachers' interviews data about schools not financially supporting their attendance to the intervention workshops. This suggests that this is the only teacher whose attendance in face-to-face workshops was hindered by the lack of support from the school. Therefore, by using triangulation of multiple sources of data, which involved cross checking findings across cases within the same data and using data collected at different times, during the intervention and post intervention, this study was able to enhance the credibility and consistency of the findings and strengthened their validity and reliability. Besides using the triangulation process to enhance validity and reliability of the findings, this study repeated the data analysis process several times. The findings obtained from following this process to analyse the data are presented in Chapter Eight. The next section discusses the process followed in analysing the data to answer the third research question of this study.

6.2.3. Influence of the intervention on the teaching practice of novice teachers

The third research question of this study was aimed at determining changes, or lack thereof, in the teaching practice of the novice Physical Sciences teachers after they have participated in the blended professional development intervention. Data collected through lesson observations before and after the teachers participated in the intervention was used primarily to answer the third research question. The lesson observations were selected because this research question was focusing on the teaching practice. Therefore, using the lesson observations enabled a comparison of the novice teachers' practice before and after they participated in the intervention, thereby revealing changes, or lack thereof, in teaching practice.

Section 6.2 above discussed how the lesson observations were transcribed. According to Creswell and Creswell (2018), this is part of organising and preparing the data for analysis. After the lesson observations were transcribed, each lesson observation transcript was divided into time intervals.

Since some of the observed lessons were shorter than 60 minutes while others were longer, as shown in Table 12, a five-minute interval was used to divide the data. Each five-minutes interval presented information regarding the teaching approach the teacher followed as they promoted knowledge building in that particular period during the lesson as shown in the picture below.

Period	Talking turns	Transcript segment
	Mr Brown	So today we are going to do the (writes) rate and extent of reaction. Rate and extent of reaction. Before we do that, we have to revise some terminologies
	Learners	Mm
	Mr Brown	Like reactants. What are reactants? If one still remembers, what are reactants? Okay we have what, reactants (Writes: reactants) that are sometimes called reagents and we have (writes) products. For every chemical reaction, there are reactants and products, right?
	Learners	Mm
	Mr Brown	Reactants are sometimes called reagents . So, they are substances that combine to form products, right?
	Learners	Mm
	Mr Brown	Products are what is formed when reactants combine, right?
	Learners	Mm
	Mr Brown	For example, if I have an (Writes: A plus B = C) equation of A plus B producing C. For a reaction we know we don't put an equal sign, we put an arrow which stands for yield or produce, right??
	Learners	Mm
	Mr Brown	Alright, for a reactant to combine we have a theory that we use called collision theory. Most of you learnt it in Grade 11, the collision theory. Let's make an example we are familiar with for maybe elements and products. We have element carbon, you all know carbon, right?
0-5 Min	Learners	Mm
	Mr Brown	Carbon reacts with oxygen, and we know that oxygen is a diatomic molecule, right?
	Learners	Mm
	Mr Brown	If carbon reacts with oxygen, what do we get as our result if these two combines?
	Learners	Carbon dioxide
	Mr Brown	We get carbon dioxide with symbol CO2, right??
	Learners	Mm
	Mr Brown	In a chemical reaction, it will not always be a case that you will get reactant A and B reacting to form C, sometimes you will get reactions where two reactants combine to form more than one product, right?
	Learners	Mm
	Mr Brown	Do you understand?
	Learners	Mm
	Mr Brown	For example, if you have magnesium, Mg, reacting with sulphuric acid which is H2SO4. What do you get? Magnesium reacts with SO4 you get (writes) Mg plus SO4 plus H2 which is a gas.
	Mr Brown	In other cases, when two reactants combine, they form one or more products. Then now, moving into collision theory. The collision theory says, this is just a revision, right?
	Learners	Mm
	Mr Brown	The collision theory states that for a reaction to occur or for A and B to combine in order to form C, these two reactants must collide.
		Collide means to bump onto one another. Collide in Xitsonga means what?
	Learners	Ku chayisana
	Mr Brown	Ku chayisana, right?
	Learners	Mm
	Mr Brown	So, for a reaction to occur, A and B must bump onto one another in order to form C, right?
	Learners	Mm
	Mr Brown	And the way they collide, they must collide at the correct orientation . Do you understand
	Learners	Mm
6-10 Min	Mr Brown	And if reactants collide at a correct orientation, we say they have effective collision. So, for a reaction to occur between atoms, ions, and molecules collision theory states that for a reaction to occur (writing on the board) ...
	Mr Brown	Ions, we know ions. Do we know ions?
	Learners	Mm

Picture 4: Lesson observations organisation

After the data was categorised into five-minute intervals, Table 5 was used to code the data. Table 5 resulted from the integration of the knowledge building approach of the pedagogical link making (PLM) framework, outlined in Figure 6, and the semantic dimension of legitimation code theory (LCT) which has been discussed in Section 3.4. As shown in Table 5 above, both PLM and LCT were used to examine data in this study. This is typical triangulation of theories as it involves the use of multiple theories to examine data (Merriam & Tisdell, 2016).

Although Table 5 was used to code the data, however, for simplicity in analysing the data, codes had to be derived. As mentioned above, codes refer to terms or designations assigned to a piece of data (Cohen et al., 2011). In analysing this data, this study used codes that were derived from Table 5 and adopted from Mudadigwa (2014). These codes are shown in the Table 18 below.

Table 18: Data coding

Approach no.	Identifying indicator one	Identifying indicator two	Semantic Gravity (SG) Strength	Semantic Density (SD) Strength	PLM Code
1	Making links between every day and scientific ways of explaining	Integration	SG++	SD-	KB1-1
		Differentiation	SG++	SD-	KB1-2
2	Making links between scientific concepts	Linking scientific concepts	SG--	SD++	KB2-1
3	Making links between scientific explanations and real-world phenomena	Simple phenomena	SG++	SD+	KB3-1
		Complex phenomena	SG+	SD+	KB3-2
4	Making links between different scales and levels of explanation	Phenomenological	SG--	SD++	KB4-1
		Theoretical	SG--	SD++	KB4-2
5		Symbolic	SG--	SD++	KB5-1

	Making links between modes of representation	Pictorial	SG++	SD--	KB5-2
		Diagrammatic	SG-	SD+	KB5-3
		Chemical equations	SG--	SD++	KB5-4
		Graphical	SG--	SD++	KB5-5
6	Making links between analogous cases	Analogies	SG++	SD+	KB6-1

The KB in the codes is an abbreviation of knowledge building, which is some kind of the pedagogical link making framework (PLM). The table above shows that each code has a number associated with it, ranging from one to six. This number represents the six main approaches in promoting knowledge building in the PLM framework. These main approaches are represented in the table above as the first identifying indicators with their order represented by the number *before* the hyphen. For example, KB6, represents the sixth approach in promoting knowledge building. The last number in the code, *after* the hyphen, represents sub approaches used per approach to promote knowledge building. For example, KB1-1 represents integration as the first sub-approach to making links between every day and scientific ways of explaining data.

Table 18 shows how Table 5 was used to code the data, thereby generating a translation device. A translational device is a method used to associate the theory into the collected data (Maton et al., 2016). It includes the use of language to provide descriptions that can be used to translate between the theory and collected data (Maton et al., 2016). The developed translational device is shown in Table 19 below. The translational device includes examples from the data illustrating each knowledge building approach as well as the relevant semantic code strengths. The translational device was used as a baseline guide to code all the lesson observations.

The use of triangulation of frameworks, as shown in the translational device below, strengthened the reliability and validity of the findings. The reliability and validity of the findings of this study was further enhanced by the use of an evaluator. The evaluator was a fellow researcher who is familiar with the LCT and PLM frameworks. The evaluator was given the translational device in

Table 19 and the coded lesson observation transcripts. The evaluator reviewed the material checking whether the translational device was understandable and meaningful, and that the coded data was without errors and aligned with the translational device. The feedback from the evaluator was implemented during the data analysis process, thereby ensuring that the generated findings were accurate and reliable.

Following the coding process described above and in the translational device, meaning from the coded data was sought. To make sense of the coded data, semantic profiles of each teacher were drawn. Examples of semantic profiles are shown in Figure 8 and Figure 9 of Chapter Three. The drawing of semantic profiles in this study provided a detailed visual description of the knowledge building approaches adopted by the teachers within each five-minute interval, from the beginning of the lesson to the end. Since two lessons per teacher were observed before and after the intervention, this entailed that two semantic profiles per teacher were drawn, showing how they were teaching before and after the intervention. This enabled a great comparison of each teacher's practice before and after they participated in the intervention, thereby revealing any changes, or lack thereof, in their teaching practice.

In addition to the semantic profiles, this study drew semantic planes of each novice teacher's lesson. An example of a semantic plane is shown in Figure 7 of Chapter Two. In this study, the semantic planes provide a summary of the lessons with regards to the semantic codes strengths, thereby showing the relative semantic code strength of the concepts and explanations that were used in each lesson. Two semantic planes per teacher were drawn. The first semantic plane presents information about the two lessons per teacher that were observed before participating in the intervention. The second semantic plane presents information about the two lessons per teacher that were observed after participating in the intervention. For clarity, each semantic plane contains the codes, as shown in Table 18 and Table 19, placed on the relevant quadrant. The presence of any code in the relevant quadrant of the semantic plane is an indication that the indicator being represented by the code was used to promote knowledge building in that lesson. Every code that was used appears only once in the semantic plane indicating that only the presence of the code is noted instead of the number of times it was used in the lesson. The semantic planes and their projected findings are presented in Chapter Nine. This was another way of visually describing the teaching practices of the teachers, enabling at glance comparison. To enhance ones' understanding of the observed changes, or lack thereof, additional evidence to support the generated meanings from the semantic profiles and semantic planes was sought from the other sources of data, e.g. interviews and/or field notes – triangulation of data sources. The findings resulting from this analysis, as well as the semantic planes and profiles, are presented in Chapter Nine.

Table 19: Translation device

Identifying indicator one	Identifying indicator two	SG Strength	SD Strength	Code	Example from data
Making links between every day and scientific ways of explaining	Integration	SG++	SD-	KB1-1	***Mr Jones****: Now let's check our equation there. Can you also see our statement there there's a lot of English in there? The are saying steam, so the steam they are referring to is the same we are used to every day.*
	Differentiation	SG++	SD-	KB1-2	***Mr Smith****: One other area which is related to this one is astronomy. In astronomy they calculate waves or the word Galaxy in geography. Stars are in this place you know that right according to The Big Bang theory they said the earth was just like a smaller tiny object suddenly it explodes then all the planets' stars started distancing from each other but in contrast when you go to church, they say this whole universe was shapeless. And then later the word was used to say let there be light and there was light, let there be some dry land and there was some dry land. Let there be water I think it's a biblical stunt but here we talk of astronomy which is different from religious things.*

Making links between scientific concepts	Linking scientific concepts	SG--	SD++	KB2-1	***Mr Brown**: Increasing the temperature, point number one, according to the collision theory, when you increase the temperature the average kinetic energy of the particles increases because energy is equal to ½mv2. The average kinetic energy of the particles increases. If the average kinetic energy of the particles since E is ½mv2 which is Ek, the kinetic energy, increasing this one, this is a constant, right?*
Making links between scientific explanations and real-world phenomena	Simple phenomena	SG++	SD+	KB3-1	***Mr Brown:** An example of a catalyst is whenever there's a wedding, they slaughter a cow on Saturday around 5 in the morning. Around 7 the meat is ready. Will the meat be ready by 7? Will it be well cooked?* ***Learners**: No* ***Mr Brown:** What our parent does it is adding cooking soda. The cooking soda is not part of the meat, but it makes the meat to be ready quicker. Take the cooking soda as a catalyst ne. Isn't that when you are cooking, you just put the meat plus water. This is what you do when you boil it. But if*

					they boil it this way, it will be ready around 1. Because our parents are scientists and educated, they put a cooking soda, so that if they start cooking around 5, by around 5H30 they are done. We eat and deal with the consequences. (Learners laugh) You know there are consequences for eating that meat? ***Learners****: Yes*
	Complex phenomena	SG+	SD+	KB3-2	***Mr Smith:*** *So, what they're saying about the red shift is that the stars the more they move away when you look at them, you'll see them as if they are red, it's like they're moving away from you. What they're saying is that after some time you'll have to rush to the moon for like 3 days, after some time we'll spend 15 days to get there. They say it's an expanding universe, the planets are moving away. That is The Big Bang theory. So, when they say redshift there is a definition in there we talk about. Let me write it down so that when it comes tomorrow, you are safe. Redshift, you are talking of light from the star shifting towards the red end of the spectrum which*

					indicates that the star is moving away from the earth. As the star is moving away from the earth, we experienced the so-called red shift. The wavelength is becoming longer and longer so that is called the red shift.
Making links between different scales and levels of explanation	Phenomenological	SG--	SD++	KB4-1	***Mr Jones:*** *What do we get from that solution? A substance ionises in water. Arrhenius says a substance ionises in water. When this substance ionises in water, H2O, it forms something which is what? Hydronium ions plus what? Something. If you can check, you can form hydronium ions from this by doing what? You can take out what?* ***Learners:*** *H*
	Theoretical	SG--	SD++	KB4-2	***Mr Jones:*** *The question says we want to check if this is acidic or basic. If we were to check that, we need to check what do we mean when we say something is acidic or something is basic and how do we know that this is basic, and this one is acidic. Then we agreed that when we have OH even if there's no minus, but if we have this formula, OH, it means this can be basic. And when we have this,*

					H_3O, it means that this can be acidic. These are the symbols that we look for to determine whether this is acidic or is basic. So, when it comes to this one, the chances of you getting OH are low but the chanced of getting this one is high. Alright, we'll let this split because automatically, these ones. When it splits, we will get this meaning that H has been added. You know ammonia, right? This was ammonia like this, and H was added on an acid. So, if H was added here to make NH_4, it means this is an acid. This was a base, only bases receive. And H was added to become NH4. So, if we have NH4 this is our base. So, if we let this acid to react with water, according to Arrhenius, it ionises in water like this, we let NH4 to ionise in water. What will happen? Since this is our salt, we take one hydrogen to this side, and we have plus. We will be left with what? Base. Do you understand?
Making links between modes of representation	Symbolic	SG--	SD++	KB5-1	***Mr Jones**: When said H3O plus. (Writes: [H3O+] [OH-] = 1 x 10 to the power minus 14) We said when we multiply the two, we get what? One times*

					ten to the minus 14. And one of these we do have which is this one (concentration of acid) isn't? ***Learners****: Yes* ***Mr Jones:*** *5.01 multiply by 10 to the minus 13 ne?* ***Learners****: Mm* ***Mr Jones:*** *Then you can divide this side by 5.01 multiply by 10 to the minus 13, 5.01 multiply by 10 to the minus 13. What do you get as the value of OH?* ***Learners****: 1* ***Mr Jones:*** *It's 1 comma?* ***Learners****:1 comma 9* ***Mr Jones:****1 comma 9..., No do it again. It's 0.02 mole per cubic decimetre like that. Is it difficult?* ***Learners****: Mm*
	Pictorial	SG++	SD--	KB5-2	***Mr Brown:*** *Okay the fourth one, what is the factor there? Again, its surface area why? Because the second one is powdered. The reason is the same as the one we have just stated isn't. If ever you are wrong on the 4th one and correct on number 3, mark yourself wrong in number 3. (Learners*

					exclaiming). How can you identify the other one to be surface area and identify the powdered one as a catalyst? How can you do that? Its surface area again. One magnesium is powdered, and the other one is ribbon, right? Same explanation. Or number 4, the one with a higher surface area is the powdered one, which is A.
	Diagrammatic	SG-	SD+	KB5-3	***Mr Smith:*** *Let's say that we're saying…oh, it's gone. A vehicle was moving from School C to Area C, ne? That's the direction. So here let's say you have two vehicles, where now you're going to exploit this equation. We want to abuse this equation. Let's draw two vehicles…you have a vehicle (draws square). Normally they'll put an arrow (draws arrow to the right), like this one, say it's twenty kg…it's travelling at…it's travelling at (takes learner's hand) …it's travelling at (Learner's name) your own velocity. There's a vehicle twenty kilograms moving to Area C at a velocity of…* ***Learner****: Fifteen.*

					***Mr Smith**: Fifteen metres per second. Normally you would write this thing, (writes) fifteen metres per second. Then they will say: it collides with a stationary truck, ne? Collides with a stationary truck. (draws) Let's say this is your truck, very nice (laughter at drawing). A (writes) stationary truck. Stationary truck, ne? Then this is my line (points to line halfway down board), it's before the collision. After this line, it's after, ne? Then after collision, the…same object (draws) twenty kg, beautiful truck…let's say, if you are going to the…driving fifteen kilometres per second, collide with a stationary truck, after the collision, the twenty… twenty kg block, moves…they will put an arrow just to confuse you…at ten metres per second (writes). Then they will say, find the V of the…how much here? The truck let's make it big (writes 500 kg) …let's make it big. Five hundred kg. If we then check at this side, this part has got its own mass, own velocity, this one it's just stationary.*

	Chemical equations	SG--	SD++	KB5-4	***Mr Jones**: Alright, I want to ask a question. (Writes a chemical equation on the board). What is the conjugate pair of H_2O? The conjugate pair of H_2O is OH, why?* ***Learners**: Base* ***Mr Jones**: It's a base and this one is what?* ***Learners**: Acids* ***Mr Jones**: (Writes another chemical equation on the board) What is the conjugate pair for ammonia? NH3. What is the conjugate pair of NH3?* ***Learners**: NH4* ***Mr Jones**: It's this one, isn't?* ***Learners**: Yes* ***Mr Jones**: Are we still clear? We said how do we get conjugate pairs? We said acid plus base, its acid plus base. When we say it's a conjugate pair, it's an acid together with what?* ***Learners**: Base* ***Mr Jones**: You must not go from acid to acid, you must go from acid to base or base to acid. So now,*

					its means this is our acid and base, and this is our base and acid. Did you get it?
	Graphical	SG--	SD++	KB5-5	***Mr Brown**: Alright, the sketch graph of the change in mass of the content of the flaks over time is shown below. It is the same as this one, you see?* ***Learners**: Mm* ***Mr Brown**: What is the horizontal part after t3, t3 is that the last part, indicate about the reaction?* ***Learners**: The reaction has stopped* ***Mr Brown**: The reaction has stopped right?* ***Learners**: Mm.* ***Mr Brown**: At what time t1, t2 or t3 is the reaction rate the highest?* ***Learners**: T1* ***Mr Brown**: T1 right?* ***Learners**: Mm.* ***Mr Brown**: Why because it is steeper. The gradient is very high right?* ***Learners**: Mm.* ***Mr Brown**: Alright, we have given a reason by referring to the graph, right?*

					Learners*: Mm.*
Making links between analogous cases	Analogies	SG++	SD+	KB6-1	***Mr Jones****: There is something (writes +), about the reaction of acid and base, when an acid reacts with a base (writes A+B) the result must be an acid plus a base, or a base plus what? Acid.* ***Learners****: Acid.* ***Mr Jones****: The outcome must be like this (circles A+B and B+A). Are we clear? If a car with a trailer could pass by this place, when it reaches its destination, it will be what? A car with a trailer.* ***Learners****: Mm.* ***Mr Jones****: Yes. Do not say it will be a bus.*

6.2.4. Influence of the intervention on the teaching and learning needs of novice teachers

The fourth research question of this study sought to investigate how the identified teaching and learning needs of the novice teachers were addressed by the intervention. Data collected mainly through interviews after the intervention was analysed and used to address this research question. Although post intervention interviews were the main source of data to answer this research question, evidence from other sources of data, e.g. post intervention lesson observations and field notes, were used to enhance the authenticity of the generated meaning. In analysing the data, the following template was used to organise and prepare the data for analysis.

Table 20: Template for analysing the data to determine the influence of the intervention on the needs of the teachers

Teaching and learning needs	Theme and sub-theme	Teachers	Post-intervention Interviews	Post-intervention Lesson observations	Field notes from intervention
Teaching and learning need	Classroom efficacy: Comprehension	Mr Brown			
		Mr Jones			
		Mr Smith			
Teaching and learning need	Professional efficacy: Professional identity	Mr Brown			
		Mr Jones			
		Mr Smith			

Table 20 above shows that the identified teaching and learning needs of the teachers per theme and sub-theme were singled out and placed in a template. Thereafter, data from post intervention interviews was segmented and grouped under each theme and sub-theme, as per Mushayikwa and Mushaikwa (2023). In addition, this data was sought out from each teacher as per the identified teaching and learning need as illustrated in the example below (Table 21).

The categorisation of data, as shown in Table 20 above, was followed by the interpreting of the data. Interpretation of the data was focused on determining whether each of the identified needs of the teachers was addressed by the intervention. If the identified needs were addressed, how were they addressed and whether the approach used was in accordance with the expectations of the teachers or not. As such, additional evidence to support the meanings obtained from the interviews conducted with each teacher was sought from their post lesson observations. The field notes written about the intervention provided evidence showing how the support, or lack thereof, provided by the intervention in addressing the identified teaching and learning needs of the teachers. These sets of evidence were also placed in the relevant space on the template above as shown in Table 21 above. The findings obtained from using the above-mentioned steps and the template to analyse the data are presented in Chapter Ten.

Table 21: Example of the data analysis process followed to answer the Fourth Research Question

Teaching and learning needs	Theme and sub-theme	Teachers	Post-intervention Interviews	Post-intervention Lesson observations	Field notes from intervention
Teaching and learning need: Teachers are facing challenges in teaching the Chemistry content. They are experiencing challenges in coming up with analogies and examples	Classroom efficacy: Content Representation	Mr Brown	*For me, whenever they came and did the topics, I understood. But to transmit that knowledge to the learners becomes a challenge. It became a challenge. So, I had to get someone because you know we are not the same. I had to get someone and say I am having a problem on this topic. Yes, if you can give me questions, I can solve them, but I cannot teach my learners. I do know the topic, wherever they are workshopping us, they are teaching us. Its fine I know. But teaching the kids, it becomes a challenge. When I come back here, I do not do justice to the topic, and I go. Then I gave them an assessment, I saw*	No instance of KB6 (making links between analogous cases), KB3-1 (making links between scientific explanations and real-world phenomena using simple phenomenon) as well as KB3-2 (making links between scientific explanations and real-world phenomena using	Relation of content to everyday life experiences was observed in the Rates of Reaction topic only (in Chemistry topics).

from everyday life that can be used to aid understanding of the Chemistry content.			*that I did not do justice here, I had to get someone else to assist. Even tomorrow, I am getting someone else to come assist.*	complex phenomenon) were observed which enables one to relate content to direct and indirect experiences.	

6.3. SUMMARY OF THE CHAPTER

This chapter has presented detailed steps that were followed in analysing all the collected data to answer each research questions of this study. The first research question of this study aimed to identify teaching and learning needs of the three novice teachers who participated in this study. As such, this chapter has explained that data collected through interviews and lesson observations before the teachers participated in the intervention was primarily used to address this first research question. However, some of the teaching and learning needs of the teachers were not apparent in the data collected before the intervention, as such the interviews and lesson observation conducted after the intervention were utilised. Furthermore, the field notes taken during the intervention workshops were utilised as an additional source of data. Since the data analysis process of this research question involved multiple methods of collecting data, lesson observations and interviews, as well as data collected at different times with reference to the intervention, this indicates that the reliability and validity of the findings of this research question was strengthened through triangulation of data collection methods and data sources.

This chapter has also explained that the needs of the teachers were classified into two themes using the teacher efficacy concept discussed in Chapter Two: classroom efficacy and professional efficacy. From the two themes, sub-themes per themes, adopted from Mushayikwa and Mushaikwa (2023), were used to further classify the teaching and learning needs of the novice teachers who participated in this study. The classroom efficacy theme includes the following sub-themes: comprehension, content representation, instructional selection, and adaptation of content. Under professional efficacy theme, the needs of the teachers were classified into the following sub-themes: classroom management, identity development, and professional integrity. These themes and sub-themes were used to determine how the identified teaching and learning needs of the teachers were addressed by the intervention, thereby answering the fourth research question of this study. The fourth research question of this study intended to determine the how the identified teaching and learning needs of the teachers were addressed by the intervention. A template showing the integration of the identified teaching and learning needs and evidence showing how they were addressed is presented to elaborate on the data analysis process.

For the second research question, which aimed to determine the effectiveness of the blended intervention workshops from the views of the novice teachers, this chapter has explained that interviews collected after the intervention were used as the primary source of data. Field notes were also used to support generated meanings. As such, triangulation of data sources was used to strengthen the validity and reliability of the findings of this research question. This chapter has also explained how the use of triangulation of data sources has generated four themes to address this research question namely: attendance; flexibility; active engagement and individual support in online and face-to-face workshops.

The third research question of this study sought to determine any changes, or lack thereof, in the teaching practice of the teachers after they have participated in the intervention. As such the data from lesson observations collected before and after the intervention was primarily used to answer this research question. This chapter has explained that triangulation of frameworks whereby the knowledge building approach from pedagogical link making (PLM) and semantic codes from legitimation code theory (LCT) were integrated and used to analyse and make sense of the data. This chapter has also explained how the integration of these two frameworks was useful in drawing visual representations, semantic plane, and semantic profiles, of the teachers' lesson per five minutes interval, thereby making it easier to determine any changes, or lack thereof, in teaching practice. The next chapter will report and discuss findings of the identified teaching and learning needs of the three novice teachers.

CHAPTER SEVEN: TEACHING AND LEARNING NEEDS OF NOVICE TEACHERS

7.1. INTRODUCTION

The purpose of this study was to determine the effectiveness of a blended professional development intervention on the teaching practices of novice teachers in rural schools of Mpumalanga province. Three teachers who were with less than five years' experience in teaching Physical Sciences and at Grade 12 level were the cases of this study. These teachers have different backgrounds. Mr Brown is qualified to teach Physical Sciences, while the other two, Mr Jones and Smith, are not qualified to teach the subject, yet they were teaching it in their respective schools. Since Mr Smith and Jones were teaching subjects that were outside of their areas of specialisation, they were considered to be teaching out-of-field. Mr Smith had sixteen years of teaching experience. He gained the sixteen years of experience from teaching Mathematics. He has less than five years of experience in teaching Physical Sciences. Given the diverse backgrounds of these teachers, the effectiveness of the blended professional development intervention may be different for each teacher depending on their individual teaching and learning needs. Against this background, this study sought to determine the teaching and learning needs of these teachers. The needs of the three novice Physical Sciences teachers that were identified are presented and discussed in this chapter. The implications of the identified teaching and learning needs of the novice teachers are presented in this chapter too. Before presenting the findings, the section below provides a summary of the data collection and analysis processes that were followed to determine the teaching and learning needs of the three novice Physical Sciences teachers.

7.2. SUMMARY OF DATA COLLECTION AND ANALYSIS PROCESS

This study used a triangulation of data collection methods, where data was collected using audio recorded semi-structured interviews and video recoded lesson observations, to determine the teaching and learning needs of the three novice teachers. The interviews and lessons observations were conducted before and after the teachers had participated in the intervention. In addition to these methods of collecting data, field notes were written during the intervention workshops. Since the data was collected at different times (before, during and after the intervention), it enabled triangulation of data sources during the analysis process, thereby strengthening the reliability and validity of the findings.

Using the teacher efficacy concept, the collected data, mainly interviews collected *before* the intervention, was segmented and then classified into two themes, namely: classroom efficacy and professional efficacy. Sub-themes of classroom efficacy and professional efficacy were adopted from Mushayikwa and Mushaikwa (2023) and used to further classify the data per theme. Classroom efficacy has four sub-themes – comprehension, content representation, instructional selection, and adaptation of content. Professional efficacy has three sub-themes – classroom management, identity development, and professional integrity. Meaning from the classified interview data was sought. Thereafter, evidence to support the generated meaning was sought from the lesson observations collected before the intervention – triangulation of data collection methods. Supporting evidence was also sought from the written field notes, interviews and lesson observations collected *after* the intervention - triangulation of data sources. The next section presents the findings per theme and sub-theme.

7.3. FINDINGS PRESENTATION

7.3.1. Teaching and Learning Needs of Novice Teachers - Classroom Efficacy

7.3.1.1. Comprehension

This study has found that all the teachers had no challenges around understanding the content knowledge of both components of Physical Sciences that is, Chemistry and Physics. The teachers understand that knowledge progresses from one grade to the next, thus promoting knowledge continuity. Mr Jones explains in the excerpt below that concepts in Physics are interlinked, hence learners must always remember what they have learned in previous grades to understand what is yet to be taught to them in the upcoming grades.

> *Alright, with that…with this subject, I think we are lucky, because mathematically we call them collinear, they join each other. If you can check, you cannot start teaching work-energy and power without teaching Newton's law. Because Newton's law is*

interlinked with what? Work-energy and power, but you must do what? Teach Newton's law first. Meaning, automatically the subject itself it's interlinked. You don't have to stress yourself. Because they will ask you a question in, let's say for example, in question seven, electrostatics, they will ask you a question about momentum. You will be able to answer that question. That is why we don't leave what we have done before, we go with it everywhere we go, until the last topic.

The teachers demonstrate some awareness of the language issues related to science in their understanding of Physical Sciences. Mr Smith, in the excerpt below, has strongly expressed the need for this language issue to be addressed as it affects learners' understanding of the content.

It's just that our learners need to be taught those Physical Sciences jargon. Ja, that's where they get confused…what do you call it…each subject has its own language. Ja, so if learners can be taught from the early stages, I think they can get better results.

From Mr Smith excerpt above, it is evident that he is aware of the language issues in science and the need for them to be addressed. He is of the opinion that this issue can be addressed if taught to learners in early grades. Mr Smith may have been referring to the use of non-technical terms, such as predict, negligible; infer; etc. Non-technical terms refer to a scholarly terminology that is used in science classrooms as general yet sophisticated words that help explain scientific terms (Quílez, 2019). The excerpt above shows that Mr Smith does not understand that non-technical terms "act as fundamental components of the reasoning processes necessary to construct, comprehend and use complex scientific ideas, which involves to employ and relate abstract concepts performing higher-order thinking" (Quílez, 2019, p. 128). As such, proficiency in this terminology must be developed in every grade and/or lesson, instead of early grades as suggested by Mr Smith.. Similarly, Oyoo (2016) and Semeon and Mutekwe (2021) report that teachers lack an understanding of the complex nature, and importance of the non-technical words in the learning process.

Mr Smith's statement also shows lack of awareness that some of the language issues in a subject vary from one topic to another. For example, each topic in a subject may have concepts that are commonly used in everyday life, although bearing the same or different meaning when used in science (Oyoo, 2009). These concepts are known as technical terms as they are specific to the science subject (Oyoo, 2009). Such language issues cannot all be resolved when the topic is introduced to the learners for the first time in early grades. Teachers in all grades must attend to these language issues when teaching any scientific topic. This is because research has shown that these languages issues function as barriers to learning and must be addressed for effective engagement with content in science lessons (Oyoo, 2009, 2012, 2016).

All the teachers have expressed how they take advantage of the language issue, where concepts in science or technical terms are used in everyday life bearing the same meaning (Oyoo, 2009), to enhance learning in their lessons. The below excerpt shows how Mr Jones find such concepts easy to teach.

> *When we get to such, we enjoy. We enjoy, really. Because I'm not struggling. I'm talking about something they know. If I was to talk about, let's say, football, if it's a team that you know and I know, when I share something of that team, which you've…like if it's a game, you are watching, I was watching, it becomes simpler for me to explain what you were watching to you. Because you are interacting, you understand? You know something. Unlike I'm giving you information that you don't even know or see. So, it becomes more simpler and easier.*

However, no opportunity to test this matter during pre and post intervention lesson observations. One of the reasons for this could be that most of the concepts covered during the lessons had been taught in previous grades, that is, Grades 10 and 11. As such, learners may have been familiar with the concepts, thus the teachers had no reason to thoroughly re-explain the concepts, taking advantage of the knowledge progressions across grades. For example, acids and bases; electric circuits; and mechanics including Newton's laws, are taught from lower grades to Grade 12, making most of the concepts covered in these topics familiar to learners. It is also possible that the concepts these teachers taught in some of the topics are not being commonly used in everyday life. For example, concepts under organic chemistry and photo-electric effect refer to matter at microscopic level.

As mentioned above, there are cases whereby a scientific concept or technical term may be commonly used in everyday life, however bearing a different meaning from that it has in a scientific context (Oyoo, 2009). Although Mr Smith expressed lack of awareness language issues, in the excerpt below he explains how such concepts should be addressed.

> *If time allows, I think it's advisable if you say, you are approaching a topic, find those words that would be often used. And then compare with the general usage in the public space. In general people will use this word, but the meaning, when we are in this subject, it's different. For example, we talk of concentration. This learner doesn't concentrate. But in physics we don't talk of such, we are meaning the amount of…is it too much or is it less? Things like that. So, we must have those key words that we explain in advance. So that when you teach the learner must not confuse that word with the word he or she encountered in the English lesson. And so, they must differentiate such problematic words.*

From the excerpt above, Mr Smith expresses the need for these concepts to be addressed. He implicitly alluded that such differentiations are not entirely important. In a way, Mr Smith is indicating that one must distinguish the use of the concepts in science and in everyday life provided there is sufficient time in their lessons for this.. This observation confirms the assumption that language issues can be addressed if taught to learners in early grades. Thus, showing his lack of awareness that some language issues vary from one topic to another \s as well as when knowledge progresses from one grade to the next, and tend to develop misconceptions in learners (Oyoo, 2016).

Mr Jones did express the need for the distinction to be made if such concepts bear different meanings in their various contextual usages. However, this was not evident during his four lessons. This is probably because learners were familiar with the concepts as they were taught in earlier grades. It could also be because none of the concepts taught are commonly used in everyday life, such as those in organic chemistry. Mr Brown, on the other hand, openly expressed how he does not differentiate for learners the difference in meanings where scientific concepts may be similar to those used in everyday life, though bearing different meanings.

I usually don't differentiate them. I think I will preach until they understand. Because they have misconceptions, whenever maybe they ask them in the exam, a soccer player will think of the momentum he knows from a stadium. But I'll tell them, they must leave their soccer knowledge.

Although Mr Brown was outright about how he addressed this language issue in the excerpt above, his view is similar to that of Mr Smith. Their lack of awareness and effective methods of addressing language issues in science lessons shows that they have low classroom efficacy around this matter. Mr Brown and Smith need to understand the role played by some of these language issues in various topics and the potential difficulty they pose in learning. They should not think of these language issues as mere erroneous understanding, they should consider them as potential inducers of misconceptions. They should also not expect learners to make explicit boundaries between school and everyday knowledge on their own as research has shown that these knowledge areas tend to strongly overlap (Oyoo, 2009, 2012, 2016; Quílez, 2019).

7.3.1.2. Content Representation

Although the teachers have not expressed any challenges in connection with Physical Sciences content knowledge, Mr Brown has a challenge in coming up with analogies that could be used to assist learners in understanding Chemistry, as shown in what he says below.

Okay, for physics, you know it's more practical, so to make examples or these analogies, it's easy. But for chemistry, you just make them there and there, where you see that okay, this one is simple. I try to make a way around. But some of the things… Chemistry is more microscopic; I also don't know anything. So, I cannot just make examples of things that I haven't seen with my eyes, at least for things I see it's easy to relate to those examples.

Mr Brown attributes the challenge of making analogies in Chemistry to the abstract nature of the content of the subject. Although Mr Brown was the only one from the three teachers who was forthcoming about this challenge, the other teachers experience the same challenge. For example, Mr Jones referred to analogous cases twice in his four observed Chemistry lessons. The excerpt below is an example of the analogous case made by Mr Jones in his first lesson observation on acids and bases before participating in the intervention.

> *There is something (writes +), about the reaction of acid and base, when an acid reacts with a base (writes A+B) the result must be an acid plus a base, or a base plus what? Acid. The outcome must be like this (circles A+B and B+A). Are we clear? If a car with a trailer could pass by this place, when it reaches its destination, it will be what? A car with a trailer. Do not say it will be a bus.*

In the excerpt above, Mr Jones was emphasising to his learners that when an acid reacts with a base, two products result, an acid and a base, instead of one product (a bus in the analogous case). The limited use of analogous cases by Mr Jones supports Mr Brown statement about the difficulty of coming up with analogies for this component of Physical Sciences. Evidence of this challenge could not be found from Mr Smith's lessons as he did not conduct any lesson on Chemistry during observation, before and after participating in the intervention. All his observed lessons were on Physics.

Although Mr Jones has not directly acknowledged the challenge of coming up with analogies to aid learners understanding of Chemistry, he was forthcoming about the challenges they face in presenting Chemistry content.

> *Ja, that's where the challenge is in chemistry. Because in chemistry we are referring to chemicals. And then chemicals mostly, most of them are not seen, you cannot tell that a reaction is running now. But you must come up with an idea or a way to show them imaginary so that a reaction is now running and when the reaction is running this is what is happening…you understand?*

Mr Jones, in the excerpt above, explains that this challenge is because of the abstract nature of the component, referring to phenomena that is beyond the naked eye's reach. Although Mr Jones is referring to the use of examples in presenting Chemistry content, his challenges resonate with that of Mr Brown about the use of analogies in Chemistry. Mr Jones revealed that it is easy to present some content for learners using examples from everyday life, such as concepts from the topic of rates and extent of reaction, it is challenging for some topics such as organic chemistry. This was evident in the observations of Mr Brown's lesson where he was teaching learners about the rates and extent of reaction.

> *The second factor is temperature. You want to make tea. To make tea, you heat up water. Why are you heating up the water? If you are heating up the water, you are increasing the temperature. Increasing the temperature allows the sugar that you have put in to dissolve quickly. Otherwise, if it was cold water from the fridge, it can take 25 minutes for the tea to be ready. Tea doesn't have to be hot. We now have iced tea; do you know it?*

In the excerpt above, Mr Brown was explaining to learners how temperature affects the rate of reaction. To help learners understand, Mr Brown used a common example from everyday life, which is making tea with cold vs hot water. From this example, learners would find it easy to understand that the rate of reaction increases with an increase in temperature. While Mr Brown was able to come up with such familiar examples on the rates and extent of reaction topic, Mr Jones did not use such examples when he was teaching learners about acids and bases and organic chemistry. From this observation, it is evident that the teachers need more exposure on the different ways they could use to present the Chemistry content to aid the learners' understanding of matter at microscopic level.

While teachers are having challenges with presenting Chemistry content, presenting Physics did not seem to be a challenge for the teachers. This is because it is mostly applicable to everyday life, thus making it less difficult to understand and relate to.

Nevertheless, scientific knowledge remains abstract in nature. As such, teachers often use code switching to make examples that learners can easily relate to while aiding their understanding. Code switching refers to the practice of alternating between two or more languages during a classroom interaction (Ulfah et al., 2021). Mr Smith explains the importance of code-switching during teaching in the excerpt below.

> *Ja, it's like this, like normally when we teach, there's this code switching…ja, if you say the concept you are trying to explain, you run out of words in English. You switch to the vernacular. Then you bring simple examples…*

Mr Smith underscored the importance of code switching and he code switched during his lessons. For example, Mr Smith used code switching to help learners determine the controlled variable of a given scenario in photoelectric effect. The use of code switching was evident across all twelve observed lessons. An example of code switching from Mr Brown's lesson is given below.

> *Mr Brown: The collision theory states that for a reaction to occur or for A and B to combine in order to form C, these two reactants must collide. Collide means to bump onto one another. Collide in Xitsonga means what?*
> *Learners: Ku chayisana*
> *Mr Brown: Ku chayisana, right?*
> *Learners: Mm*

In the extract above, Mr Brown was simplifying the meaning of collide for learners and checking if they understood by asking them to give the meaning of the concept in their home language. It is worth noting that although the teachers tended to code switch in their lessons, English remained the main language of teaching. However, learners frequently used their home language to interact with their teachers, especially when responding to questions during lessons. These findings corroborate those of Mavuru and Ramnarain (2020) who found that teachers code-switch to enable conceptual understanding and to encourage learners to critically voice their opinions on scientific issues. Mavuru and Ramnarain (2020) also found that the use of code-switching tended to disadvantage the learners as they found it difficult to complete assessments that needed English responses. Although code switching may enhance learners' conceptual understanding, it does not improve their proficiency in the language of teaching and learning. This is a concern because learners must be competent in this language to be able to show their level of understanding in writing/assessments.

It is the view of this study that the observed interaction of learners using their home language to engage with their teachers was a result of their lack of proficiency in the language of teaching and learning, English. This was also revealed by Mr Smith when he said,.

> *English! English is a problem. So, I wonder, why? Don't we have English teachers or English subjects in the school? We do. Why not understand this simple language. So,*

at some stage, you'll say I'll be creating politics here. Because you may wonder, what are the English teachers doing that make these learners not to understand this simple English or subject. So, it means you as a teacher in physics you are going to teach English.

From the excerpt above, Mr Smith is explaining how English, the official language of teaching and learning, is a challenge to learners. According to Mr Smith, this challenge causes some of the teaching time to be lost in their lessons because they must help the learners to understand the language of teaching and learning for them to understand the lesson content. However, from the observations made, none of the teachers were taking some of their teaching time to help learners understand the language. At most, one would expect the teachers to encourage the use of this language in their lessons. Observations showed that learners were free to use their preferred language to interact with their teachers.

The findings and discussion presented above indicate that these teachers have low classroom efficacy when it comes to the representation of Chemistry content. This is observed in the way they find it easier to relate Physics content, compared to Chemistry, to everyday life events using analogies. There was more code switching in Physics than Chemistry topics. This may have been the result of the abstract nature of the Chemistry content. According to Mavuru and Ramnarain (2020), this could be the result of the vocabulary gaps in African languages for scientific concepts, which makes it difficult to translate scientific concepts between English and the learners' home language.

7.3.1.3. Instructional Selection

Mr Brown mentioned challenges that came with Covid-19 in the choice of teaching and learning strategies that teachers could use to enable understanding.

> *Okay, at the moment we are under lockdown due to Covid-19, and you know with it they are not allowed to interact with another. So, they sit in rows, I give them information, I give them information, they go home, and I expect them to come the next day knowing. But if ever maybe Covid was not here, then maybe I would group them and give them that so that they discuss. And now it's not possible.*

Here Mr Brown explains that teaching became teacher centred, where he would pass information to learners and expect them to have understood when he meets them again in the next lesson. Mr Brown explains that he would adopt a rather different strategy if there were no lockdown restrictions. He would allow learners to work in groups and discuss the lesson content. Although Mr Brown was the only teacher who raised this concern, it may have been common to all the teachers. This is because in all the twelve observed lessons, learners were all directly engaging with their teachers and hardly interacting with their peers. Although the pre-intervention data was collected during the heavy lockdown restrictions, the post intervention data was collected when lockdown restrictions have eased, significantly. As such, it is likely that teachers are used to directly engaging with learners, leaving little room for learners to engage with their peers. This may have been influenced by the pressure coming with teaching Grade 12 learners resulting from the limited teaching time and need for 100% pass rate and quality passes from all education stakeholders. Thus, it is necessary that other effective ways of engaging learners be introduced to the teachers. These methods should assist teachers in effectively engaging with their learners, in and out of classroom.

While lockdown restrictions may have influenced teachers' instructional choices, lack of appropriate teaching resources for the subject seem to play a major role in their choice of instruction. For example, all the teachers were observed drawing illustrations on the chalkboard of the phenomenon at microscopic level and explaining them. Instead of making such illustrations, the teachers could have given learners access to scientific models for them to construct organic molecules and observe how elimination, substitution and addition reactions take place in Chemistry. They could have also given learners access to electric circuits kits for them to construct circuits and measure current, voltage, and resistance in Physics. Nevertheless, the teachers do not have access to such teaching and learning resources and can only rely on examples that are familiar to learners to aid and/or enable understanding.

While the above-mentioned examples enable physical manipulation of Physical Sciences learning material, there are also digital tools that teachers could use to enhance understanding, such as simulations. In the excerpt below, Mr Brown explains how he could use simulations to make illustrations and aid learners understanding.

> *There are these things. It's just that my computer doesn't support them. They are called PHET simulations. Ja, hey, those I really want them. Because maybe if I get those ones, even for chemistry, they simulate everything. They simulate everything you can see, if ever an electron is moving to another atom, it shows the electron moving on. A learner won't forget that.*

This excerpt reveals that Mr Brown believes that access to such teaching and learning resource could elevate his challenges when presenting Chemistry content. Although Phet simulations are free of charge, one would need access to the internet and/or a compatible Java application to run them. Mr Brown's challenge in accessing this teaching resource is the lack of compatibility of his laptop with the application. Mr Smith and Jones did not mention anything about Phet simulations, nor did they use them in their observed lessons. This could be because these two teachers are not familiar with simulations, hence they did not mention them. It could also be that these teachers do not find simulations useful, hence they believe that the teaching of this subject can be made easier through practical demonstrations, as Mr Smith states in the excerpt below.

> *This subject, we must teach it with demonstrations. There must be demonstrations, not explaining, we must demonstrate…meaning like practicals. Ja, you must perform, and they will see, oh, this is what he's saying. If you mix this thing and this thing, the colour will be like this one. If you put this indicator, it will change to this colour. But if you don't have it, it's always theory, theory, theory. And sometimes it is discouraging. Ja,*

it's like a bible stud, you're talking of heaven. They haven't seen those things. So, but if like there was a supply of those things, that was going to be a smooth subject.

Here Mr Smith states that demonstrations enable the learners to see the subject as being practical and relatable. It also promotes interest in the subject. However, his statement is limited to macroscopic observations, which is insufficient as learners are taught about matter at a microscopic level in the subject. Whether learners can see colour changes, or a live chemical reaction, observations are useful if learners cannot relate them to what they cannot see, at microscopic level. Thus, a practical demonstration that is limited to macroscopic observations does produce the desired understanding of the subject by the learners. Mr Jones underscores the importance of macroscopic observations, such as live chemical reaction, instead of just mentioning how the macroscopic observations could pave way for a deeper understanding of matter at microscopic level.

It is important to note that teachers were provided with materials to conduct practical experiments for chemistry and physics, except for Mr Smith. Mr Jones and Brown were not observed using the practical materials in their lessons post intervention. This is what they had to say about the practical materials:

***Mr Brown**: The ones for practicals, I have never used them because the multimeter is not working. Let me say, the ones for experiments, I never used them because we were done with experiments. I only showed them that if they are talking of…. I was doing electricity with them showing them that what a cell is and copper or connecting wire, light bulbs. I tried to connect and couldn't and I just took back to the container and placed it at the office.*

***Mr Jones**: Ok, that one we did not have the opportunity to run those practicals. But I took 3 learners, we tried with 3 learners and unfortunately it didn't work out because I think I needed a thermometer or what? It was missing, so that's why we couldn't finish off our stuff. But we did try, we did try, because I ended up trying something else, I don't know whether it's thermometer or what. It's even there (pointing at a storage locker).*

From the two statements of Mr Brown and Jones, it is evident that the teachers attempted to conduct a practical to test the equipment. However, they could not proceed with the practicals because there was some material that was missing or was not working. For example, Mr Brown could have used the material to illustrate to learners how the brightness of the lightbulbs changes as more cells are added in series or parallel connection. This demonstration would have been successful in enabling understanding of series and parallel connection in electric circuits even without the use of multimeter to measure voltage, current or resistance. The act of showing learners the components of a circuit is an indication that the teacher lacks understanding of further experiments that he may conduct with the learners using the available materials to enable understanding.

These teachers' failure to proceed with their intended experiments could be because they are unfamiliar with micro-kits as these set of materials are not yet common in the country. Additionally, the teachers may not know how to prepare experiments other than the ones prescribed for assessments. Thus, they find the process of having to prepare these experiments frustrating and time consuming as they do not know what else to do with the materials other than conducting the prescribed practical experiments. It is therefore necessary that the teachers be workshopped on how to work with micro-kits and develop experiments that can aid understanding of each topic.

Mr Brown indicated that he conducts practical experiments only for assessment, and not to aid learners' understanding. This suggests that Mr Brown does not believe that practical experiments are effective in aiding understanding because they only depict matter at macroscopic level and do not illustrate what is happening at microscopic level.

The three teachers underscore the importance of practical experiments, especially on how they provide insight into the macroscopic level. None of these teachers see practical experiments beyond this limited view. Their limited view of practical experiments coincides with current research trends in chemistry teaching that they tend to focus on one level of representation, thereby promoting lack of understanding of matter beyond macroscopic level (Rantih et al., 2019). As such, whether these teachers had a science laboratory and necessary equipment, for Chemistry in particular, they would not be able to help learners understand matter beyond the macroscopic level.

As such, it is important to note that these teachers require some workshops on how they can effectively use practical experiments to aid understanding and promote interest in learners. These workshops can address the below concern raised by Mr Smith.

> *In fact, a science school should have a lab where sometimes learners will go there and perform. But…with us in rural areas, they struggle. No wonder our learners, they prefer to score high in paper one. Because it's more of maths than chemistry. You see, in chemistry you talk chemical equilibrium, always abstract. Ja, you must put that in her head, or his head, until they memorise, some will say memorise, you'll understand later. So, it's a problem.*

From the excerpt above, Mr Smith alludes to the importance of practical experiments in science lessons, and how lack of teaching resources such as a science laboratory, has an impact on their teaching. Mr Smith explains that Chemistry is taught in a manner that allows learners to memorise the content. Since the content is memorised, not conceptually understood, learners struggle to provide correct answers if a different scenario to the one memorised is provided. Thus, they have better conceptual understanding of Physics than Chemistry, as Physics content is easily relatable to everyday life phenomena.

In the absence of necessary teaching and learning resources for Physical Sciences, Messrs Jones and Smith explain how they rely on recorded videos of experiments to help learners fulfil the assessment requirements of the subject.

> *We take video recorded lessons, we sit down, we watch, and then maybe we can watch it three times or four times, and then when we have understood everything… Actually, we take everything from what we see and what we hear, not something that we are doing practically ourselves. But we see from a video…televised. So, we take recordings from what we see…that's what we rely on, we rely on videos.*

Mr Jones uses video recorded experiments in his teaching. Learners watch the video repeatedly and record their observations. While this technique worked for Mr Jones and Mr Smith, it does not help learners acquire the necessary skills they need to be in a science field, such as handling material and making measurements. Mr Smith's school has a computer lab that he would use when learners were to watch video lessons. He, however, indicated that the computer lab is not readily accessible.

> *Well, with videos we only use these video lessons, and we usually take them to the lab there and then they see what is happening…ja. If time allows. But at some stage you find that there's no time. The space is small there. The other teachers are also fighting to use the same space.*

Mr Smith explains that the space in the school computer lab is small to accommodate all his learners. Furthermore, all teachers want to use the space, thus limiting their time of usage and access. Unlike Mr Smith's school, Mr Brown and Jones schools have projectors that they can use to display Physical Sciences content. The use of a projector helps these two teachers in displaying the matter at microscopic level, through videos and simulation, when possible, thus reducing the difficulty of presenting Chemistry content. These two teachers have not raised any issues on utilising and accessing this equipment for teaching though there did not use the projectors during their lesson. Mr Jones, however, claim to have used the projector to allow learners access to one of the teachers' workshops for the intervention.

The findings and discussion presented above portray the challenges faced by these teachers in teaching Physical Sciences in rural schools. Their challenges are similar to those described by Mukeredzi (2013) and DBE (2017) regarding inadequate/lack of teaching and learning resources in rural schools. However, they also show that teachers lack classroom efficacy in using available resources such as micro-kits to aid conceptual understanding. This lack of classroom efficacy seems to emanate from their lack of knowledge of experiments they can do with learners other than the ones prescribed in the curriculum. Furthermore, these teachers' view of the significance of experiments in teaching and learning is limited to a macroscopic level, thereby exposing their lack of classroom efficacy in effectively using experiments to promote conceptual understanding. It is the view of this study that these teachers lack practical knowledge, which as reported by Mushayikwa and Lubben (2009), has an effect on classroom efficacy in addition to SCK and PCK.

7.3.1.4. Adaptation of Content

Mr Brown and Mr Smith explained how they spend more than the stipulated time on the annual teaching plan and curriculum document. According to Mr Brown, he is always left behind because he must remind learners of what they had learned previously before proceeding to the current lesson content. He adds that some of the time is spent re-explaining content because learners have challenges grasping it, thereby letting the pace of the lesson being determined by the learners' understanding of content. The challenge of time management is common experience among novice teachers (Ntsoane, 2017). However, Mr Brown's reasons for this challenge are different to those of Mr Smith, as shown below.

> *Each year we have a different group of learners. So, when we say, why last year we performed better, this year, forgetting these learners their basic skills are different. Their knowledge gaps. At one stage some were good, come the following year, hey! Very slow learners, very slow. In a…like a chapter needs four hours…and I spend two weeks. So that's the problem.*

According to Mr Smith, as shown in the excerpt above, he spends a lot more time than required because each group of learners he teaches each year is different and, therefore, has different learning needs. The difference that Mr Smith refers to is the knowledge gaps and nature of learners, whereby some learners are categorised as not grasping content as quickly as others do. It is easy for Mr Smith to relate his challenge of teaching time to knowledge gaps because he does not teach all the groups of learners from Grade 10 to 11. He shares these classes with another teacher, although Mr Smith is solely responsible for teaching Grade 12 learners.

From this understanding, knowledge gaps seem to exist because learners are taught by different teachers with different approaches at different grades prior to Grade 12. If Mr Smith does not understand the previous teacher learning style, which the learners are used to, he is likely to attribute learners' challenges with understanding content to knowledge gaps. It is, therefore, necessary that a proper hand-over of learners be done by teachers as learners change grades and/or teachers. This helps the current teacher of learners to understand the content covered by the previous teacher, what was left behind, the type of challenges experienced by the learners with each topic, and which teaching and learning strategies were effective for the group of learners.

Teachers need to understand the type of learners they have. Mr Smith mentioned that some learners do not grasp content as quick as others. This is an indication that they need to adapt instruction and content to suit the learning needs of their learners. If instruction is tailor made to the needs of the learners, less time is taken in teaching the content and no learner is left behind. This is possible because school A and C, had less than 24 learners in total while School B had about 75 learners split into two Grade 12 classes. Adopting teaching and learning instruction and content to learners needs involve identifying challenges with the content, such as misconceptions, and pre-requisite content knowledge. This requires constant planning and reflection from the teachers. However, Mr Jones seems to believe that experience eliminates the need to plan, as shown below.

> *Physical Sciences, it goes with experience. With my experience, I no longer need a textbook for me to go and teach. Anything that a person can just ask me, I can just teach them. Physical Sciences teachers, we enjoy because I will just go to class and introduce the topic and then I will be done. Everything will be there on the board, and I will be done teaching, and then we take questions, we'll be able to answer questions.*

In the excerpt above, Mr Jones explains that with his less than 5 years of experience teaching Physical Sciences, he does not need to prepare for the lessons anymore. This lack of planning, and lack of reflection, is the main source of teachers' lack of understanding of their learners. The lack of planning shows that Mr Jones considers teaching to be about having the SCK. This view is limited as teaching is not entirely about having SCK, it is also about using PCK to transform SCK, enabling access to scientific knowledge (Shulman, 1986). It is through this understanding that a teacher is able to adapt SCK to his/her learners' needs, thereby limiting misunderstandings and the amount of time spent on each topic. It is important teachers plan and reflect on their lessons to improve practice.

While Mr Brown and Smith did not explicitly mention that they do not plan and reflect on their lessons, they may be having the same view as Mr Jones. This is because they also mentioned that they always to catch up with the annual teaching plan as a result of learners taking longer to grasp content. This observation shows that these teachers have low classroom efficacy in terms of adapting content to the learning needs of their learners.

7.3.2. Teaching and Learning Needs of Novice Teachers - Professional Efficacy

7.3.2.1. Classroom Management

One of the challenges Mr Jones is faced with when it comes to managing his classroom is insufficient textbooks for his learners. Mr Jones elaborates on this challenge in the excerpt below.

> *When they give textbooks, remember now that they are 75, if I request textbooks, if I have 50 now, or requested to add, and then I'll be left with five extra, if next year a hundred comes, it means I'll be short. And the numbers have been increasing ever since I got here. The number is increasing, it's not decreasing.*

According to Mr Jones, the school does not have budget for textbooks for each year. The excerpt indicates that sufficient textbooks, with surpluses, were bought once a while ago. However, since the number of learners taking Physical Sciences increases each year. As a result, they are running short of textbooks. This shortage of textbooks was evident in Mr Jones first lesson observation pre-intervention where learners were seen to be sharing textbooks. This challenge was not observed in Mr Brown and Smith's lessons. Lack and/or inadequate textbooks are a common challenge in rural schools as it was also reported by Mukeredzi (2013) and DBE (2017).

Mr Smith explained that it is equally challenging to select a textbook for use by each grade. According to Mr Smith, some of the textbooks they choose to use are not of good standard too. He said,

> *The only issue could be that the teacher chose a poor textbook, which is not well written. Because at some stage we had an argument, when we go for marking, the marking centre will have their own recommended science definitions or what-what. Then one will argue, 'no, my learner wrote this law from this textbook'. This textbook passed all the standards, so why now we're saying this definition is skewed or lacks some content?*

The issue of poor-quality textbooks that was raised by Mr Smith in the excerpt above is addressed by the use of study guides and exam guidelines that are readily accessible to teachers. While exam guidelines are accessible to teachers only, study guides are accessible to everyone, including learners. Although study guides are accessible to everyone, the school does not provide them to learners. For learners to have study guides, they must buy them. Thus, few learners, if not none, have access to study guides. Nevertheless, guidance must be provided to teachers in selecting good textbooks to use with their learners. This is significant because learners use textbooks to reconcile and enhance their understanding of the content covered in class post lessons. Thus, if the textbook is poorly written, it may perpetuate learners' misconceptions. It is, therefore, the view of this study that these teachers be equipped with knowledge of selecting textbooks on their own for their learners, thereby improving their professional efficacy.

Besides assistance with textbooks, Mr Smith and Jones share the view that someone else must sometimes teach their classes. According to these teachers, such visits tend to improve learners' focus as shown in the excerpts below.

> ***Mr Smith:*** *Normally our learners when they see a different face, they create their own atmosphere. When they see an unfamiliar face, they tend to attend to the person. But if the face is familiar, aah! This one, we know you, we know you.*
>
> ***Mr Jones:*** *You know our learners have that mentality of hearing new things from someone else, even if it's the same thing hearing a different voice, somehow, it helps, it draws their attention, they listen. You know, when you keep eating, pap and beans, when someone else cook the very same pap and beans, it feels different. So, I can say if maybe we were given the opportunity that our facilitators would come at least to our schools sometime just to do it themselves, that would be beneficial.*

The excerpt above shows that Mr Jones and Mr Smith believe that learners pay more attention to people they are unfamiliar with than their own teachers. The excerpt reveals that even though teachers could be workshopped on how to teach some topics, these teachers seem to believe that their facilitators should come to their classes and teach the learners. In other words, facilitators should physically demonstrate the teaching strategies they are workshopping teachers on. Thus, Mr Jones and Mr Smith are requesting that some workshops be conducted with their learners. While it is a genuine concern for teachers to request facilitators' presence in their classes, the excerpt above also reveals that these teachers seem to not believe much in their own abilities to implement the learned strategies.

While Mr Jones invites people to teach his learners to take advantage of their attentiveness to unfamiliar faces to improve their understanding, as his teaching load is weighing heavily on him. Mr Brown shares the same experience as Mr Jones. This is evident in the following excerpts.

> ***Mr Jones***: *If it's possible, the Department can at least give us or bless us with one teacher to assist us. If we can have someone who can assist us…let's say, I do paper one maybe paper two, or I do paper two, they do paper one. Unlike having…you know, if I have…like with other subjects, geography have three teachers, they teach one subject, one grade, one class, three of them. This one is teaching this topic, this one this…myself…you see I must start and complete and then come back to the other paper. Though I'm not complaining. Trust me, I'm not complaining I enjoy this subject. Yet, if there was one to assist, I'd be happy.*

> ***Mr Jones***: *I see now there are pamphlets that they are forwarding to us from Wits, Physical Sciences for grade 12. These pamphlets outline the topic and then there are questions from previous question papers. Some of them [referring to questions] they just made them themselves. Those questions are helping us, because when I do teach and then give them, they can go home and try. When they come back, we do the corrections, at least there is progress. Unlike me having to sit down and compile those pamphlets. At what time? Because I must be in class, I must prepare, and I must be somebody at home…like I must balance all this. So at least if I have someone who is assisting in that area it makes my life easier. Ja, such a help can be helpful.*

> ***Mr Brown***: *Okay…if possible, I need extra hands. You know I can…since I told you we have limited time, and in that limited time you can't expect me to go an extra mile every day. Sometimes where necessary I need to rest. If ever maybe some programme can start around maybe here in Area A, you know, whereby maybe on weekends,*

learners can go and do, maths and science and stuff. If maybe such can happen it would be a relief.

The first excerpt above expresses Mr Jones' request for an additional teacher to assist him with teaching Physics from Grade 10 to 12, as he is currently the only Physical Sciences teacher in the school. In the excerpt, Mr Jones explains how he could teach Physics while Chemistry is taught by the other teacher, as part of sharing teaching load. In the second excerpt, Mr Jones reveals the relief he got from the pamphlets consisting of questions for each topic that learners can use to study. In the last excerpt, Mr Brown is requesting extra classes for his learners where they will be taught by someone else, other than him, on weekends so he can get some rest.

Although the needs of these two teachers seem to be different, the excerpts reveal an outcry by these teachers for help in managing their classes so they could have some time to rest and be with their families. These teachers are always at school teaching. For example, Mr Jones had one of his second lesson observations pre-intervention on a Sunday morning. Mr Brown, on the other hand, had his second lesson observation post-intervention after 4 PM. The lesson observation ended at 6 PM. Mr Smith also mentioned that they have study camps on weekends and holidays, and morning and afternoon classes that they attend with their learners. Although Mr Smith has not mentioned the support that Mr Jones and MR Brown explicitly requested, he claims to be spending the equal amount of time at school with his learners as Mr Brown and Mr Jones without sufficient rest. However, there is no evidence that of Mr Smith spending time with his learners outside working hours to serve as evidence for his claim.

It is important to note that this lack of rest the teachers are experiencing is because of their schools' underperformance in the past. However, it is unhealthy for these teachers to spend so much time at school, without adequate rest. Lack of rest may cause burnout and chronic diseases, especially if they do not obtain the desired results as seen in the excerpt below.

If you check those model C schools, they don't have the so-called extra classes, weekends and what-what, Sundays camps. What's wrong with us? You come in the normal teaching hours, you go after school, you come weekends. So, you can see *there's a problem. There's a problem. Sometimes I may ask, is it because this subject is offered in English? Some will say, no! Some will say, it's just that we are not serious.*

In the excerpt above, Mr Smith is expressing his frustrations over the persisting underperformance of their schools after putting a lot of effort in conducting extra classes for the learners. As Mr Smith has indicated, it is quite concerning that these schools continue to perform poorly even after investing significant amount of time on the learners with hopes of improving their performance. This persisting poor performance may be resulting from teachers' lack of attention to the learning needs of their learners, as indicated above, where they focus more on disseminating SCK instead of transforming it. However, thorough research has to be conducted to understand how extended working hours do not correlate with the learner performance. This also raises the need for extensive research contrasting the teaching and learning in well and poor performing schools, outlining areas of improvement.

The persisting poor performance in these schools may also be the result of excessive workloads, as this study has showed that these teachers are spending a lot of time at school teaching, with little time to rest and spend time with their families. Ogbonnaya and Awuah (2019) note that excessive workloads reduce the effectiveness of the teachers. Overworking these teachers to improve performance is likely to yield unintended results, whereby teachers find it difficult to cope leading to their resignations from their teaching posts and leaving the teaching profession. This will, therefore, perpetuate the current challenges faced by DBE in retaining teachers in rural schools, especially in these gateway subjects where very few teachers graduate per year (CDE, 2011)

Since these teachers are all novices in the profession and/or teaching Grade 12, Caspersen and Raaen (2014) explain that it is common for these teachers to underperform as they are still in the transfer shock period. It is during this period that these teachers require support, especially Mr Brown and Jones who are also new to the profession. However, the excerpts above show that these teachers are all alone, having to spend excessive amount of time at school since there is a limited supply of teachers in rural areas (Masinire, 2015). Ntsoane (2017) reported that lack of support leaves these novice teachers with only two options, to 'swim or sink' on their own. These teachers need support in managing their workloads, consequently, developing their professional efficacy.

7.3.2.2. Identity Development

The three teachers have different reasons for intending to participate in the intervention. For example, Mr Brown was hoping to obtain teaching and learning resources that he can use to aid his learners' understanding of the subject content knowledge. Mr Jones wanted the intervention to help him improve the performance of his learners. Mr Smith has openly expressed that he would like to learn new methods of teaching the different topics of the subject from the intervention. These varying reasons all indicate the need for these teachers to associate themselves with the subject, thereby developing their professional identity as Physical Sciences teachers. Developing professional identity will improve these teachers' professional efficacy.

None of these teachers have mentioned any specific areas they needed assistance with. For example, Mr Smith has mentioned that he used to have challenges teaching the topic of Acids and Bases. He explains that he would ask a fellow teacher to teach this section for him. Through this assistance as well as participating in cluster meetings, Mr Smith explained that he no longer finds that topic challenging to teach. However, there is no evidence to support Mr Smith's assertion as he did not teach the topic of acids and bases in all his observed lessons before and after the intervention.

From the interview conducted after the intervention, it was learned that Mr Brown is struggling to teach the topic of acids and bases and chemical equilibrium as shown below.

> *For me, whenever they came and did the topics, I understood. But to transmit that knowledge to the learners becomes a challenge. It became a challenge. So, I had to get someone because you know we are not the same. I had to get someone and say I am having a problem on this topic. Yes, if you can give me questions, I can solve them, but I cannot teach my learners. I do know the topic, wherever they are workshopping us, they are teaching us. Its fine I know. But teaching the kids, it becomes a challenge. When I come back here, I do not do justice to the topic, and I go. Then I gave them an assessment, I saw that I did not do justice here, I had to get someone else to assist. Even tomorrow, I am getting someone else to come assist.*

From the excerpt above, it is evident that Mr Brown is struggling to teach these two topics. According to the excerpt above, Mr Brown claims to understand the content of these topics as he can successfully answer all questions related to it. However, he cannot transform his knowledge of these topics, making it accessible to his learners. This is not the only topic that Mr Brown is struggling with. He is also having a challenge with teaching Electric circuits as shown below.

> *There's a topic I am having a challenge with and if it was covered, I don't know how many percent I would have gotten. I never knew that these learners had a challenge until the trial exam. Its electricity in physics.*

In the excerpt, Mr Brown is explaining that he is finding electric circuits challenging to teach. However, Mr Brown's awareness of this challenge seem to have been caused by the poor performance of his learners on the topic during the preliminary examinations. Since the preliminary examinations were written after the intervention had taken place, Mr Brown believes that his learners would have performed well had methods of teaching this topic been shared during the intervention. The excerpt above also shows that Mr Brown, just like Mr Jones, wants to obtain a 100% pass rate on this subject. This is in line with Letloenyane and Jita's (2020) observationb that teachers engage in professional development to improve the achievement of their learners.

Mr Jones, on the other hand, had challenges with teaching the topics of Electrochemistry, Electrodynamics and Rates and Extent of Reactions, as he said.

> *There are certain things which I was not quite sure of. And some things, even if you can try to search from your textbook or Internet, you might find that explanation as saying that experience count. So, someone with experience has encountered these challenges not once or two times. Later they found a solution.*

The excerpt above reveals that Mr Jones had sections within the above-mentioned topics that he was not sure of, hence which gave rise to the challenges he faced when teaching these topics. Mr Jones did not elaborate on the nature of his challenges.. However, his excerpt is emphasising the importance of the experience of the facilitators of professional development. According to Mr Jones, those with experience in teaching the subject will be well versed with the challenges that novices are likely to experience. As such, they are better able to mentor novice teachers. Mr Jones would like to associate himself with individuals of well-established professional identities, whom he can learn from as he develops his own professional identity. Although Mr Jones view is directed to the characteristics mentors should possess, it is related to Mukeredzi's (2013) call for a more focused and comprehensive mentor training for teachers taking on the role of a mentor in school-based professional development.

Although Mr Smith did not raise any concerns with teaching any topic in the subject, he has the same intentions as Mr Brown and Mr Jones. He indicated that he needs to learn new methods of teaching the various topics in the subject. He, however, believes that not all learners can learn Physical Sciences, as he notes that.

> *Physics it's not like any learning area. It's more of an abstract subject, which if a learner opts to follow that route, the learner must be gifted mathematically. The learner must be able to interpret scenarios. And if given a formula the learner must know exactly what quantity to use, where to substitute, use a correct unit, things like that.*

Mr Smith's sentiments above underscore his belief that the subject must be taken by learners who are mathematically gifted. Mr Smith classify such learners as 'science material'. This is evident in the below excerpt.

> *The type of learners we are having this year they are not science material. So, it's like we are forcing them or maybe it's us or the parents at home who said they must study science, while the ability, capacity to do the subject is lacking.*

Although the nature of Physical Sciences requires one to have a certain level of competency in mathematics, Mr Smith does not seem to be having a positive attitude towards his learners. This attitude seems to emanate from their poor performance as well as his view of learners' attitude towards their own education as shown below.

> *They do not commit themselves. Actually, it's not about being forced to do something but if you are willing to do the subject, you can do it. But the type of learners we are having, they don't mind, they don't care in fact. They don't care. Out of a class of 24*

> *learners, its only 4 who passed. So, you can see they failed dismal. If we compare, check with the other learning areas for the same class, the performed the same in Maths, same performance in Physics. So, you can see that something is not right. They didn't perform well.*

Here Mr Smith raises concerns around the poor performance of his learners in Mathematics and Physical Sciences. According to Mr Smith, beside the learners not being 'science material', the learners are not committed to their own education. Mr Smith's observation is based on learners' poor performance in the preliminary examination, whereby 4out of 24 learners performed well in Physical Sciences. Mr Smith is of the opinion that Physical Sciences must be taken by learners who are committed to the subject and are mathematically inclined too. In other words, if learners are not mathematically inclined, though putting in the effort, they would perform well in the subject. Since the focus of this study was on teachers, the claims made by Mr Smith regarding his learners' attitude remain unverified. However, the poor performance observed by Mr Smith is a major concern because of the huge difference between the number of learners in his class vs those in Mr Jones.

It is clear that Mr Smith's attitude against his learners emanates from his conceptions of Mathematics and Science learners developed through 16 years of experience in the profession teaching Mathematics. This is a concern because research shows that peoples' attitude influences their behaviour and academic performance in class (Ekperi et al., 2019; Ulug et al., 2011). Mr Smith's conceptions of Mathematics and Science learners are likely to affect his attitude towards the learners, posing constraints in the manner in which he interacts with them. Ulug et al. (2011) explains that negative attitudes lead to failure, as such, Mr Smith's attitudes are likely to negatively impact the performance in his learners, thereby affecting his professional identity as a Physical Sciences teacher. His attitude may have resulted from his years of teaching experience in Mathematics.

It is also possible that Mr Smith may not be entirely having a negative attitude towards his learners but experiencing a transfer shock because he is teaching out of specialisation, and a novice in teaching Grade 12 Physical Sciences. According to Caspersen and Raaen (2014), transfer shock stimulate stress, burnout, leading to ineffective teaching and poor learner performance. Teaching off-field and the observed poor learner performance in Physical Sciences challenges professional identities of Mr Smith, both as a Mathematics teacher for 16 years and a Grade 12 Physical Sciences teacher. This challenge affects Mr Smith's classroom and professional efficacy.

7.3.2.3. Professional Integrity

There is no doubt that these three teachers are dedicated to the profession. This is evident in the amount of time they spent with their learners at school, and how the poor performance of their learners concerns them. In this regard, Mr Jones says,

> *You know, with physics and maths, you need to go the extra mile of not only being a teacher in class. At times you need to become an entertainer, at times you need to become a motivator. You need to be all these things, so the class can be accommodated. Some learners need to be motivated. Some learners need to be entertained in the classroom. And you need to check, you need to see all that, and you need to cater for all.*

In this excerpt Mr Jones explained how he needs to adopt different roles in the classroom to keep learners motivated and interested in the subject. The role of being an entertainer for learners was observed in three teachers' lessons. During these teachers' lessons, they would make jokes, causing the learners to laugh. By doing so, the atmosphere in the classroom would be joyous. This role of the teachers makes them approachable, rather than intimidating. Only teachers who are committed to the profession take their time to adopt these different roles during their lessons for the benefit of their learners. It is therefore, without a doubt that these three teachers are dedicated to the profession, thus their professional efficacy in this aspect is unquestionable.

Although these teachers have shown an extent of dedication to the teaching profession, these teachers have their own preferences over the components of Physical Sciences. For the three teachers who participated in this study, they seem to prefer Physics over Chemistry as shown by Mr Brown's excerpt below.

> *Okay, I enjoy in the physics part, the Physical Sciences, because that's where work is done actually. Ja, that is where the training is. In the physics part that is when you see*

that this person is like, that is how we diagnose the person. This person, how he thinks, how he does things.

Mr Smith warns against unethical behaviours that may be caused by preferences given in the excerpt below.

This thing of saying this teacher is good in paper one, he will make sure he only teaches paper one the whole year.

Teachers' preference of a component over the other appears to be influenced by their competence in teaching that component. Mr Smith, in the excerpt above, explains that such preferences may cause the teacher to focus on teaching that component only for the entire year, while neglecting the other component. A similar concern was raised by Zulu (2018). Such behaviour is unethical as a Physical Sciences teacher in South Africa is expected to be competent in both components of the subjects. This is in contrast to other countries in the SADC region where components of Physical Sciences are offered as standalone subjects allowing learners and teachers to choose to specialise in both or only one of them (Ncube, 2014).

Such unethical behaviour is likely to be observed in off-field teachers, who specialised in one component of the subject in their qualifications, thus incompetent in the other component. Mr Smith and Mr Jones are off-field teachers who specialised in Physics in their BSc degrees. However, Mr Jones' years of teaching experience in Physical Sciences are more those of Mr Smith. From the many years of teaching Physical Sciences, Mr Jones may have gained the required competence to teach the subject and all its components. Thus, Mr Jones was able to conduct Chemistry lessons, which are outside of his qualification specialisation. As such, it is likely that Mr Smith taught Physics topics only for his observations because his insecurities about his competence in Chemistry, although he was the one who raised this concern. This view is further supported by his absence from workshops that focused on Physics topics. Mr Smith attended workshops that were focused on Chemistry topics only (see Table 22 in the next chapter). Mr Smith needs professional development in Chemistry more than in Physics.

Professional development may be beneficial to every teacher, including qualified Physical Sciences teachers. This is because it provides teachers with an opportunity to revise their SCK, which enables them to correct any incorrect information they may have. Mr Jones warns against teaching of incorrect knowledge below.

> *What you tell a learner as a teacher, they take it seriously and they keep that in mind. So, as a teacher you must be careful. But if not, you will tell them lies and they will keep those lies, you see, and they will destroy the world.*

Mr Jones warns against the dangers of sharing incorrect information. He explains how incorrect information taught by teachers to their learners can destroy the world. This is critical because teachers are the first and significant source of information for learners. Everything taught by the teachers, learners will listen to and keep as part of their knowledge. Thus, it is unethical for teachers to share incorrect information with the learners. It is therefore vitally important that all teachers go through continuous professional development for their own benefit and that of their learners, especially since there are constant developments to SCK. Such workshops ensure that teachers maintain professional integrity in their classrooms by sharing up to date information with their learners and competently teaching all components of Physical Sciences. Professional development ensures that teachers remain effective in their teaching, thereby improving their classroom and professional efficacy.

7.4. DISCUSSION OF FINDINGS

On classroom efficacy, under comprehension, this study has found that teachers do not experience difficulties in understanding the Physical Sciences content. There challenges are around understanding and transforming language issues in the subject to enable learning. The findings of this study corroborate those of Oyoo (2016) and Semeon and Mutekwe (2021) who observe that teachers' lack of understanding of the complexity, nature, and importance of the non-technical words in the learning process. Oyoo and Nkopodi (2020) add that teachers are unaware that learners have poor understanding of non-technical terms, leading to poor conceptualisation of SCK. Hence, these teachers are of the view that non-technical terms must be taught in early grades only for learners to develop their proficiency. Although the abovementioned view was apparent in Mr Smith, it may be shared by all the teachers as they did not seem to develop learners' competency in non-technical terms in all the observed lessons.

The teachers' lack of understanding of the significance of non-technical terms in the learning process may be the result of lack of knowledge and skills on how to develop learners' competency on this aspect of their lessons. It is for this reason that Oyoo (2016) recommends that language issues be part of the teachers' training curriculum. This observation calls for the need to reflect and review the curriculum in higher education institutions. Oyoo and Nkopodi (2020) add that a policy should be devised that requires teachers to address language issues in their lessons, helping learners to be proficient and to understand SCK. These are important recommendations because they ensure that teachers are equipped with the required knowledge and skills to assist their learners in learning Physical Sciences. Oyoo (2016) further note that the knowledge on how to promote non-technical terms competency in a subject should be included in professional development initiatives. This implies that this knowledge should be part of the content focus of professional development, similar to SCK and PCK, as shown in Figure 4. This ensures that the teachers are developed on this language aspect of each content area addressed by the professional development initiatives, thereby developing their competency in each of the language issues per topic in the subject.

Professional development initiatives, teacher training curriculum and trainers should conscientize teachers on the use technical terms in other contexts other than science with similar and/or different meanings, as reported by Oyoo (2009).. As such, they should equip teachers with knowledge and skills on how to address such language issues through the use of integration and/or differentiation (Scott et al.,2011).. Such awareness is significant as it helps teachers understand that these language issues have the potential to hinder learning, especially when the meaning of the technical terms is different from the one used in everyday context, thereby causing poor learner performance. The importance of this awareness is emphasised in this study because Mr Brown and Mr Smith lacked this awareness, which may negatively impact the learning process.

Mr Brown clearly stated that he does not use differentiation to help learners understand the meaning of technical concepts in science when they are also used in everyday life with a different meaning. Rather, he expects learners to make such distinction by themselves. Although Mr Smith has some awareness of these language issues, he emphasised that differentiation can only be utilised when time permits during the lesson, thereby implying that it is not very important. As argued by Oyoo (2016), these language issues must be part of the teacher training curriculum and be included in professional development initiatives, such as the one being examined in this study. In this study, an inclusion of language issues into the professional development intervention is expected to improve these teachers' classroom efficacy, in a way that aids conceptual understanding and reduces poor learner performance.

Another language issue that was discovered by this study, although falling under content representation, is the general competency in the language of teaching and learning (LOLT). This study found that the teachers are aware that learners are not adequately competent in the LOLT. As such, teachers often resorted to code switching during their lessons and allowed learners to use the language they are comfortable with, instead of developing their general competency in the LOLT. This promotes conceptual understanding in learners, encouraging them to critically voice their opinions about scientific issues (Mavuru & Ramnarain, 2020). It is important for teachers to permit learners to use vernacular languages during their lessons because they do not have the knowledge and skills to assist them with general competency in the LOLT within their subject of specialisation. It is critical for teachers to be equipped with the required knowledge and skills of developing learners' general competency and proficiency in LOLT in a lesson while teaching them their teaching SCK. This should not take away the roles and responsibilities of the English teachers but should be adopted as supplementary action to accelerate learners' proficiency in the language, thus enabling their access to knowledge. Mavuru and Ramnarain (2020) warn that failure to do so results into continued challenges for learners to complete assessments that needs English responses.

This study also found that the three teachers have challenges with teaching Chemistry content, as part of content representation in classroom efficacy. This includes coming up with suitable analogies and examples from everyday life that enhance learners' understanding. This emanates from the abstract nature of the Physical Sciences component, perpetuated by lack of appropriate teaching and learning resources for the subject, thereby affecting instructional selection. Since it is challenging to come up with analogies and examples from everyday life to relate to Chemistry content, appropriate teaching and learning resources should be utilised instead. This suggests that appropriate and affordable teaching and learning resources should be provided to the teachers to help them to effectively teach Chemistry. Information on relevant and readily available teaching and learning resources that could be used to aid learning should be shared with the teachers, such as simulations and how to effectively utilise them in teaching. Readily available teaching and learning resources may also include household materials such as transparent plastic bottles (instead of beakers and text tubes) vinegar and baking soda. The information may also include *do-it-yourself* products that teachers can design from readily available materials and use for teaching and learning, such as the ball-and-stick model made of dough and toothpicks used to teach about physical and chemical properties of matter.

This study has reported that the teachers were provided with micro-kits that they could use to demonstrate when teaching a chemical and physical phenomenon. However, this study found that these teachers were not able to use the material to conduct experiments other than the ones prescribed on the curriculum. This was evident in the study where both Mr Jones and Mr Brown explained that they abandoned the micro-kits when they were testing them using prescribed experiments because one of the apparatuses was missing or not working. This study gathered, from the testing experiments that they conducted, that they missed numerous learning opportunities with the working and available material. It is the view of this study that the missed learning opportunities were the result of the teachers' limited knowledge on possible experiments they can perform with the available and working materials. This then implies that teachers need to be given knowledge and skills of conducting experiments, other than the ones prescribed on the curriculum, based on available materials to promote learning. This aspect should form part of the content focus of a professional development intervention, a component of professional development shown in Figure 4, as this knowledge is part of SCK and PCK. Including this aspect is expected to improve teachers' classroom efficacy as they will learn different approaches that they can use to aid learners understanding using what is available to them.

In addition, teachers should be educated on how to relate macroscopic observations (observations within naked eye reach) to microscopic observations (observations beyond the naked eye reach), particularly in Chemistry. This is because Chemistry knowledge must be understood at three levels of representation, namely macroscopic, microscopic, and symbolic level (Rantih et al., 2019). Teachers must help learners make these relations during the learning process. However, this study found that the three novice teachers' knowledge and use of experiments was limited to elicitation of interest in learners. Their limited view of experiments promotes lack of understanding of matter beyond macroscopic level (Rantih et al., 2019). With this limited knowledge about experiments, the teachers would have challenges in relation to what learners can see with their naked eyes to what they cannot see and using symbols to represent it. Such relation can be difficult to achieve by any teacher without proper training, and even more challenging for those teaching out-of-field. As such, this affects both teachers' content representation and instructional selection, significantly affecting their classroom efficacy. This finding implies that these teachers must be professionally developed on effectively using experiments and relating their observations on all three levels of representations in Chemistry.

This study also found out that the teachers had challenges on adapting content to the level and needs of the learners. This was noted in their responses where they explained how they are always behind according to the annual teaching plan (ATP). These teachers attributed this challenge to knowledge gaps that learners have and have to be addressed before teaching them new knowledge. They also attributed this to poor learner understanding of the topic. In contrast, this study attributed this to lack of proper planning for each lesson. Lack of planning was a factor that the teachers mentioned and associated with their experience in the subject. When a lesson is well planned, a teacher is able to identify and devise strategies to use to address teaching and learning barriers foreach topic while teaching the required SCK within the designated time as per the curriculum and ATP. Therefore, professional development initiatives along with DBE should work together in emphasising the significance of novice teachers going into classroom having completed lesson plans for every lesson topic. Professional development initiatives must help the teachers in planning lessons by identifying possible misconceptions and learning difficulties that learners experience with each topic. Appropriate strategies must also be devised to address the identified possible learning hindrances. This aspect falls under content focus; however, teachers should complete these lesson plans as part of active engagement in professional development and must receive constructive feedback as outlined in Figure 4.

On the professional efficacy theme, under classroom management, this study observed that the teachers would experience challenges on selecting quality textbooks for their learners. In some cases, the textbooks are not enough to accommodate all learners. As such, they need to develop learning material for the learners to use. The learning material must comprise of questions and notes, similar to a textbook. However, teachers explained that they do not have the time to develop these materials and would be pleased if professional development initiatives can assist them in this regard. It is common to have expectations from professional development initiatives, however, teachers need to develop some skills of their own to help themselves with their workload. This includes the skill to develop teaching and learning material, resembling textbooks, that they simply update once a year and reuse. This implies that professional development initiatives should equip the teachers with these skills to help them ease their workload. Teachers should then actively engage in the professional development interventions perfecting these skills using available support. The same skill set could be useful to teachers in selecting textbooks for their learners when possible and in addressing the experienced shortage of textbooks.

In terms of professional identity, this study found that the three teachers participated in the intervention to learn strategies that would help them to obtain 100% learner pass rate in their subjects. Obtaining a 100% learner pass rate will help the teachers to obtain recognition in their profession, thereby enhancing their professional efficacy in terms of professional identity. However, research shows that although professional development initiatives are expected to eventually address poor learner performance, they do not always obtain the desired changes (Kraft et al., 2018). Kraft et al. (2018) reveal that most professional development interventions failed to change teaching practices and improve learners' academic achievement. As such, this study suggest that professional development initiatives should directly address learner performance to improve it. It should not be expected to be the resulting product of changes in teaching practice of the teacher, as viewed by Darling-Hammond et al. (2017). This implies that improving learner performance should be made as a separate goal in teachers' professional development, similar to change in teaching practice, to be addressed whereby teachers will be equipped with knowledge and skills that will improve learner performance while enhancing understanding. This will make the professional development initiative more meaningful to the teachers as it would be directly addressing their concern.

Addressing learner performance separately does not entail teaching for assessment. However, it highlights the need to develop a systematic coaching approach for the learners which helps them better understand the SCK. For example, the development of pamphlets which contained text and diagrammatic summary of the content for each topic as well as sample questions were used in the intervention to ensure that learners had the material that they could use to study on their own. This would reduce learners' dependence on their teachers for information and learning activities, thereby lessening teachers' pressure. This approach is also cost effective, sustainable and can implemented in different contexts. Addressing learner performance entails making learners aware of what is expected from them, how they can meet the expectations, the relevance and usefulness of these expectations in the current grade and beyond. This may include using assessment guidelines, such as exams, to strategically coach learners while teaching is in progress. This will help learners to measure their own cognitive development as they realise what they can and cannot do, enabling them to take ownership of their own learning. This would also provide teachers with an overview of learners' weaknesses and how to address them. Such an approach provides learners with the necessary information to help them to do well in the subject, boost their self-efficacy, thereby influencing their performance.

In order to improve learner performance, this study observed that the teachers were spending a lot of time at school teaching their learners. They would attend classes in the mornings, afternoons, holidays, and weekends without resting adequately. It is worth noting that these teachers have displayed great sense of commitment towards the profession by spending those excessive hours teaching. However, due to the lack of rest caused by the excessive number of hours spent in class, the teachers have realised a need for assistance with their workloads. Assistance with the workload will allow the teachers to spend time with their families and rest, where possible, reducing the probability of burnout, stress, and poor learner performance commonly experienced by novice teachers leading to attrition (Caspersen & Raaen, 2014). However, it is the view of this study that these teachers could have been performing well provided they had the relevant knowledge and skills to address learning barriers that are significantly affecting learner performance. This implies that the professional development intervention that is being reviewed in this study must examine the teaching practice of these teachers, determine causes of poor learner performance, and use that information to develop approaches that may help them shape their teaching practice and improve learner performance.

7.5. SUMMARY OF THE CHAPTER

This chapter has presented and discussed the identified teaching and learning needs of the three novice Physical Sciences teachers. The needs that were identified emerged from using triangulation of data sources and data collection methods, which included lesson observations, interviews, and field notes. This chapter has also discussed the implications of the identified teaching and learning needs of the teachers. The discussed implications basically pinpoint what is expected from the blended professional development intervention given the identified teaching and learning needs. The next chapter presents finding that reveal the teachers' views regarding the effectiveness of the blended professional development intervention workshops.

CHAPTER EIGHT: EFFECTIVENESS OF THE BLENDED INTERVENTION WORKSHOPS - VIEWS OF THE NOVICE TEACHERS

8.1. INTRODUCTION

The purpose of this study was to examine the effectiveness of the blended professional development intervention in improving the teaching practice of novice teachers in the rural schools of the Mpumalanga province. The aim of the intervention, whose effectiveness is being examined, was to assist teachers in teaching examinable Grade 12 Physical Sciences topics and to provide teachers with strategies that would help them prepare their learners for the final examination while also improving their pass rate and overall performance. This did not exclude the strategies put in place to promote knowledge building already. The intervention comprised of face-to-face and online workshops; hence it is blended. A total of eight workshops (each workshop being two hours long), four online one and four face-to-face ones, were conducted with the teachers. Two of the four face-to-face workshops were conducted with the learners of Mr Brown, whereby the facilitator taught the learners, in the presence of the teachers. This was to show the teachers how to implement the shared teaching and learning strategies. Since the intervention was targeted at helping the teachers, it was significant that the effectiveness of the blended approach adopted by the intervention be determined from the views of the teachers. This was essential considering the findings of the previous chapter about the diverse teaching and learning needs of the teacher as well as their implications for these teachers' professional development. Hence, this chapter presents the findings and discussion of the views of the three novice Physical Sciences teachers regarding the effectiveness of the blended intervention workshops. Implications of these findings are also explained, following the findings presentation. Before presenting the findings and discussion, the next section summarises the data collection and analysis process followed to obtain the findings presented in this chapter.

8.2. SUMMARY OF DATA COLLECTION AND ANALYSIS PROCESS

To determine the views of the three novice Physical Sciences teachers regarding the effectiveness of the blended intervention workshops, this study used mainly the interview data collected *after* the teachers participated in the intervention program. In analysing the data, codes, through open coding, were generated. The generated codes that seem to go together were grouped together- axial coding, and themes were derived. Four themes were generated from the data – attendance, flexibility, individual support, and engagement in online and face-to-face workshops. These themes present a comparison of the affordances and constraints experienced by the teachers as they attended face-to-face and/or online workshops. Triangulation of data sources was used to provide additional supporting evidence to the generated meanings. This involved seeking evidence from the field notes written during the intervention workshops and interview data across the teachers. The findings obtained from the brief summary of the data collection and analysis process outlined above are presented in the next section per theme.

8.3. FINDINGS PRESENTATION

8.3.1. Effectiveness of the Blended Intervention Workshops: Attendance in online and face-to-face workshops

The findings of this study show that teachers find attendance of online workshops more challenging than that of face-to-face workshops. For example, Mr Brown noted that access to data bundles is major hindrance to attending online workshops.

> *For those workshops that are online, data is expensive. If you request the school to help you with data, they say no or promise to assist but they never do. There was this one time where I attended half of the session, because I received a text stating that I have used 50% of the data.*

Mr Brown is here raising his concern over the affordability of data bundles required to access online workshops, explaining that while data bundles are expensive to purchase, he is not receiving financial support from his school to buy them so that attends the workshops. As such, he had to stop attending one of the workshops halfway through as he was notified by his service provider that he has less than 50% remaining of his data bundles. Mr Smith, just like Mr Brown, expressed the need for the provision of data to improve attendance in online workshops as shown below.

> *Sometimes, like the online one, you must have enough data to listen and participate, all of that. So, you might find that a teacher might be logged in now for 10-15 minutes, then he's out, just like that. I don't know how, but if there were some sponsors somehow that could help supplement a little in terms of data, that could be another issue.*

In the excerpt above, Mr Smith explains the that lack of data deprives teachers of an opportunity to attend and participate in online workshops. Although Mr Jones did not mention data bundles as being a factor affecting his attendance in online workshops, he shares the same experience as Mr Brown and Mr Smith. This is evident in the table below that is showing the amount of time the three teachers spent attending the online workshops.

Table 22: Attendance duration of the teachers per online workshop

	Newton laws Workshop (01-Sep-21)	*Vertical projectile (03-Sep-21)*	*Acids and bases (15-Sep-21)*	*Rates of Reactions (17-Sep-21)*
Mr Brown	39m 23s			1h 32m
Mr Jones	42m 23s			1h 36m
Mr Smith			1h 40m	1h 40m

Table 22 above shows that the teachers had excellent attendance on the 17th of September, attending the workshop for almost two hours. This excellent attendance may be attributed to the fact that the content covered on that workshop was to be written by the learners in the preliminary examination on Monday (20th of September 2021). The same can be said about Mr Smith's attendance on the 15th of September, after missing the other online workshops. Additionally, Mr

Smith could have attended these two workshops to enhance his knowledge on Chemistry as Chapter Seven has shown that he may be incompetent on this component of Physical Sciences.

Beside the excellent attendance on the 17th of September, Table 22 above shows that all the teachers attended only two out of the four online workshops. In addition, Mr Brown and Mr Jones attended for less than an hour on the 1st of September. This poor attendance of online workshops shows that the teachers may not had sufficient data bundles to access all organised online workshops. Similarly, Mukuna and Aloka (2020) note that the cost of data is one of the factors that constrained online learning in rural areas in South Africa. Campbell (2019) also found out that the lack of data is a barrier that negatively affects the level of engagement during any online activity, regardless of the context. One of the ways of addressing this challenge, as suggested by Mukuna and Aloka (2020), to provide teachers with adequate resources, including data bundles and technological learning devices, to enable access to online opportunities of professional development.

The findings above reveal that attendance to workshops is influenced by the nature of support offered to teachers from their schools. On this matter, Mr Brown said,

> *I had to go attend physical workshops with my own money, If I mention here at school that Wits people want us to meet physically at School D. They won't give me money to go there. I expected the department or my school to support me financially so that I can attend. If ever they give me money to go attend, I will be owing it to them to be there. But if I am using my own money, I can decide not to waste my money to go there, and I won't go.*

From the excerpt above, Mr Brown explains how good financial support from either the school or the Department of Education guarantees teachers' attendance of workshops. Mr Brown further indicates that without financial support from the school, he can opt not to attend workshops. However, the fact that Mr Brown was able to attend all face-to-face workshops, and some online workshops shows his dedication to the development of his professional identity.. The excerpt above shows the significance of support that schools should provide to their teachers to improve their attendance of workshops in general. These findings corroborate the financial challenges of face-to-face professional development that were presented by Powell and Bodur (2019).

Unlike Mr Brown, Mr Jones indicated that poor network coverage is one of the hindrances in attending online workshops, as shown below.

> *So, the only challenge with online, you know online we'll be experiencing maybe network problem. You know. I remember there was one which I couldn't even log in because of network. I remember I was not around; I was on a workshop and at the place, my network was not supported, I am using Telkom. So, if I'll be having a challenge of network, it means I won't be able to attend.*

While it is said that one can attend online workshops anywhere, Mr Jones indicated that poor connection resulting from poor network coverage can obstruct attendance, thereby hindering engagement. Poor network coverage is one of the factors that of Mukuna and Aloka (2020) found to be constraining online learning in rural areas in South Africa. It is therefore important that measures to counteract the effects of poor network coverage be considered and implemented by organisers of the intervention to improve attendance in online workshops.

These challenges on attendance of online workshops do not seem to have left a good impression on the teachers, thereby affecting their level of engagement. This is concerning since most workshops of the intervention were conducted online, thereby bringing into question the effectiveness of the blended professional development in shaping their teaching practice. However, the teachers have a positive view of the face-to-face workshops, except for the support issue Mr Brown alluded to above.

8.3.2. Effectiveness of the Blended Intervention Workshops: Flexibility in online and face-to-face workshops

Although other teachers find online workshops to be more flexible than face to face workshops, Mr Brown does not. Flexibility is key advantage of online professional development (Powell & Bodur, 2019). By flexible, the teachers, Mr Jones and Mr Smith, refer to the opportunity offered by online workshops for teachers to attend together with their learners. Mr Smith elaborates below.

With the online one, you can attend with your learners. You can project it there and they listen together. But with that one that requires the teacher to rush in there, you may find that he rushes in there but when he comes back, some of the things won't be delivered the same way they were delivered that side.

Mr Smith explains how a projector could be used to display the screen of the facilitator so that learners listen along with the teacher. Mr Smith explains that such facilities are available for face-to-face workshops. He elaborates that having to attend with the learners enabled them access to first-hand information shared by the facilitators without any distortion. However, it is important to note that teachers attend the online workshops with their learners without the knowledge of the facilitators. As such, learners cannot directly ask the facilitators any questions they may have. Mr Jones explains how he managed to attend with his learners the 17th of September workshop.

I was able to connect here and then they were listening. Yeah, they filled this place. They were watching here and if we are busy asking questions, they were listening. I was asking questions as a learner, they were also listening and benefiting, taking notes.

From the excerpt above, Mr Jones is explaining how he would ask questions on behalf of his learners during the workshop. While the teacher found this strategy helpful, it is important to note that the workshop was conducted with the teaching concerns of the teachers in mind. Thus, it was at pitched at higher level of comprehension for learners and the content could confuse the learners. Whenever teachers attend with their learners, the facilitators need to be made aware so that they cater for their learning needs when facilitating the workshops. It is important to note that this flexibility is cost-effective as only one person had to join the online workshop. Thus, Powell and Bodur (2019) note that online professional development is flexible, in this case for both teachers and facilitators.

It is important to note that the teachers were granted access to the recordings of each online workshop. Teachers could use the recordings if they missed the workshops. However, none of them had anything to say about the recordings. One of the reasons for this could be that the teachers do not know that they could access the recordings. It could also be that the teachers did not have time to view the recordings, as they are usually under time pressure (Hunt-Barron et al., 2015; Tsiotakis & Jimoyiannis, 2016). Dios and Charlo (2021) show that this recording feature is one of the reasons behind the preference of learning online rather than face-to-face. This is because they increase access to knowledge since even those individuals who were absent in the synchronous session have access to the recorded lessons. The recorded lessons enable individuals to revisit components they did not entirely understand during the synchronous session. Furthermore, the recordings can be watched any number of times and anyhow (Dios & Charlo, 2021). Despite the flexibility of recorded lessons, some teachers did not leverage this benefit, especially those who did not attend the workshops.

The findings of this study show that only Mr Jones and Mr Smith found online workshops to be effective. These teachers have a positive view about online workshops because it satisfied their need for facilitators to visit their schools and teach their classes. From these two teachers' perspective, although the facilitator is not physically present in their classes, learners are able to see and interact with the facilitator online using technological devices, such as projectors. Thus, learners pay attention, thereby improving their understanding of the content as taught by the facilitator.

8.3.3. Effectiveness of the Blended Intervention Workshops: Individual support in online and face-to-face workshops

Although Mr Smith has a positive view about online workshops, he feels that they do not provide room for one to directly interact with the facilitator, as shown below.

> *Personal interaction is also important because with this online thing [online workshops], one might be busy with something else this side. They may be watching but they won't participate fully. But if sometimes we do a physical one [face-to-face workshop], we get to see people, you share your concerns directly to the right person.*

In the excerpt above, Mr Smith is alluding to the importance of one-on-one interaction in face-to-face workshops. His statement reveals that some teachers may have concerns and/or questions that they may want to raise directly with the facilitator. This may be the case for off-field and novice teachers who are concerned about being looked down upon if they raise concerns that they need assistance with during the workshop. Thus, these teachers may prefer to engage privately with the facilitator at the end of the workshop, where possible.

Mr Smith explains that the one-on-one interaction is available during face-to-face workshops only, where they could get individual support by meeting up with the facilitators during breaks and/or at the end of the workshop. From observations made during online workshops, none of the teachers would remain behind to chat with the facilitator. However, it was common in face-to-face workshops that teachers would chat with the facilitators during breaks and at the end of the workshops. The reason for this could be that teachers were not aware that they could remain behind at the end of online workshops and directly engage with the facilitator. It may have also been an issue of data bundles as indicated above. Furthermore, the intervention did not provide consultation times that could be used by teachers to obtain individual support. The consultation times would have contributed to the professional development of off-field and novice teachers.

Since Mr Smith explicitly raised this concern, it is an indication that he was hoping to get the individual support from the intervention without fear of being judged and looked down upon through the utilisation of breaks and remaining behind to chat with the facilitator at the end of the workshops. Hunt-Barron et al. (2015) also indicates that teachers require privacy during online professional development as they would opt to directly engage with anyone who can assist them instead of posting their concerns or ideas publicly. It is therefore the understanding of this study that individual support is important during the teachers' professional development, thereby aiding the effectiveness of the intervention.

8.3.4. Effectiveness of the Blended Intervention Workshops: Engagement in online and face-to-face workshops

Mr Smith speaks to active engagement in online workshops. According to Mr Smith, the facilitator might not see what the teachers are doing during online workshops, whether they are following what is being shared or are busy with other tasks not related to the workshop. In the excerpt below, Mr Brown expresses his dissatisfaction with online workshops in terms of engagement.

There was one that we had on memo discussion paper two. I had troubles marking paper two because I had just logged in when they greeted me to say 'Hey, how are you?' And I said and fine and hung up. They don't know that I'm out and I did my things. So, I think you should do more physical workshops than online ones, if possible.

Here Mr Brown explains that he may pretend to be participating while attending to other tasks that are unrelated to the workshop. Mr Brown, just like Mr Smith, seems to believe that the physical presence of the facilitator compels him to pay full attention to the workshop. Similar concerns were raised by Gherheș et al. (2021) about participants turning off their cameras in synchronous lessons. Gherheș et al. (2021) argues that with cameras turned off, there is no evidence that participants are paying attention and actively engaging with the content. It also for this reason that Mr Brown finds online workshops to be ineffective in promoting active engagement. In the excerpt below, Mr Brown implicitly alludes to another important factor contributing to poor engagement in online workshops.

The online one, I'm alone, you do not see me, you only see any of the screen that you project there. In most case, I would be busy with my things putting the phone down. The was a day when they asked me a question, I was not even there. I was called saying they are looking for me. I was busy with my things. So, I lose concentration quicky with online workshops because I'm in my space and if am in my space I might even sleep.

Mr Brown notes that he easily gets distracted during online workshops. As a result, he would attend to other activities that are not related to the workshop.. He also mentioned that he would fall asleep during online workshops. It is thus important to encourage active participation during workshops. During the intervention workshops, it was observed that the teachers were rarely given activities to complete during the intervention, during both online and face to face workshops. In addition, there were no opportunities for collaboration amongst the teachers during the workshops.

The intervention workshops were dominated by the facilitator who were sharing information with the teachers. Lack of active engagement is likely to cause anyone to feel bored, thereby causing sleepiness. Desimone (2009) and Patton et al. (2015) assert that teachers must be treated as active learners during their professional development. As such, active participation becomes pivotal to the success of the professional development initiative.

Sleepiness may also be caused by lack of relevance and usefulness of the shared information or workshop. This is possible because not many teachers found some of the topics covered during the intervention workshops to be challenging (see Figure 11 in Chapter Four). For example, Figure 11 shows that only two out of thirteen teachers identified the topics of Vertical projectile motion, Electrodynamics and Electrochemistry as challenging and needed assistance on. These findings reflect the importance of coherence in professional development, as outlined by Desimone (2009) and Patton et al. (2015). For professional development to be coherent, the information shared must be relevant and useful to the teachers. In other words, professional development must be informed by the teaching and learning needs of the teachers and should assist the teachers in meeting these needs (Powell & Bodur, 2019). By focusing on the least challenging topics, the professional development intervention appears to have overlooked the needs of the teachers.

Since active engagement was rarely promoted during the workshops, the intervention took similar stance as those from the Department of Education. According to Bantwini and King-McKenzie (2011), teachers remain passive throughout the Department of Education workshops and are expected to implement what was said during the workshops when teaching. It is therefore not surprising that Mr Smith tried to implement the same strategies shared during the intervention workshops and failed to obtain the desired results as he noted that only four out of twenty-four learners in his class performed well in the preliminary examinations. The facilitators and organisers of the workshop did not observe any of these teachers to examine how well they implemented the strategies they shared with them and give them constructive feedback to improve their teaching.

Active engagement in professional development could be improved by, firstly, integrating authentic tasks. Secondly, active engagement could be promoted by using the coaching and/or mentoring model. This model encourages one-on-one interactions in promoting professional development (Kennedy, 2005). Since there were some teachers who were not having challenges with some topics, they could have been used as mentors to assist others with the topics they find challenging. A typical example of this is learned from Mr Brown who sought assistance from a fellow teacher in some topics he found challenging. Lastly, active engagement could be promoted through formation of *active* communities of practice. Activeness is emphasised here because a community of practice was formed in this professional development, however, it was not actively interacting as required/expected. Therefore, it did not serve as a setting where teachers could acquire knowledge and contribute meaningfully.

8.4. DISCUSSION OF THE FINDINGS

This study gathered that teachers were experiencing challenges in attending online workshops compared to face-to-face workshops. Their attendance of online workshops was constrained by limited access to data bundles. Chapter Four explained that the teachers were not given data bundles to access the online workshops of the intervention due to financial constraints and it was not part of the research project/intervention grant to support teachers with the required data bundles. As such, it was expected that this would hinder teachers' access to online workshops as research had revealed that the cost of data bundles tends to negatively affect attendance and level of engagement in online learning opportunities (Campbell, 2019; Mukuna & Aloka, 2020). This suggests that for improved attendance and engagement in online workshops, teachers must be provided with data bundles. This was also demonstrated in the framework of effective blended professional development framework (Figure 4), which shows that teachers must be provided with digital tools to enable access to online learning opportunities. The digital tools include laptops/tablets that teachers need to use to join online workshops as well as data bundles. Figure 4 shows that access to these digital tools is important in enhancing the effectiveness of blended professional development interventions. Thus, failure to provide these resources to the teachers results in poor attendance and disengagement during online learning opportunities, as shown in Table 22.

While access to digital tools may assist in improving teachers' attendance and engagement in online workshops, these resources are not useful if the teachers are in areas where there is poor network coverage. This study found that besides the costs of data bundles, their attendance in online workshops was constrained by poor network coverage(Mukuna &Aloka,2020). Chapter Four explained that the constraints posed by poor network coverage were addressed by recording the synchronous online workshops with the recordings being shared with the teachers. However, there is no evidence to show that the teachers did view the recordings, especially those who missed some of the workshops due to various reasons including poor network coverage. Therefore, the effectiveness of this countermeasure remains unknown.

Due to poor network coverage which is beyond the control of the intervention and the observed challenges experienced by teachers, e.g. time pressure (Hunt-Barron et al., 2015; Tsiotakis & Jimoyiannis, 2016), it is important that the intervention organisers reconsider holding synchronous online workshops and opt for asynchronous ones. This would entail that the intervention design should be carefully structured to permit guided self-paced learning that is embedded in authentic tasks to promote active engagement, as shown in Figure 4. Through guided self-paced learning and authentic tasks, the intervention will offer controlled yet desired flexibility for teachers, thereby being responsive to the time pressure experienced by the teachers and counteract the impact of poor network coverage. However, this design will require the facilitators to have in-depth technological pedagogical content knowledge (TPACK), as shown in Figure 4, so to make the experiences of these teachers worthwhile. Additionally, adequate individual support should be made available, a component of effective blended professional development framework shown in Figure 4.

Although the costs of data bundles and poor network coverage negatively affected teachers' attendance of online workshops, they still found this type of a workshops to be flexible. For example, the teachers could attend the workshop along with their learners, although learners' attendance may have been unknown by the facilitators. Attending with learners saved the teachers time because they would not have to attend the workshop and then go back to their classes to share what they learned with their learners. This approach was considerate of their pressure due to time, as reported by Hunt-Barron et al. (2015) and Tsiotakis and Jimoyiannis (2016). The teachers added that learners obtain first-hand information when they attend with their teachers, that has not been distorted by the teachers based on their own understanding. While this appears plausible, it is important that it is done with the knowledge of the facilitator to ensure that learners needs are catered for, and the content is delivered at their level of understanding as it was the case with workshop 7 and 8 conducted on the 2nd of October 2021.

An alternative to asynchronous workshops would be to opt for face-to-face workshops. These workshops require teachers to be physically present to acquire knowledge. They are not impacted by electricity and poor network coverage, thereby making them a better option. However, this study found that attending these workshops is costly for the teachers. Mr Brown explained that he does not receive any support from the school to attend these workshops. He reveals that this discourages him as it shows lack of support, yet he is expected to produce a 100% learner pass rate. This implies that interventions should always choose venues that are easily accessible and closer to reduce the cost of attending them for the teachers. Provided sufficient funding is available, the intervention should consider compensating teachers for their travelling costs, thereby reducing their burden of having to shoulder all the responsibilities for their professional development. It would also be helpful for intervention organisers to establish an agreement with the DBE, whereby the DBE will be responsible for compensating the teachers for their travelling costs. This would show support and encourage the teachers to attend the workshops.

In addition to face-to-face workshops being unaffected by data costs and poor network coverage, they provide opportunities for individual teacher support. Teachers would chat with their facilitators individually or in pairs/ small groups, about the teaching of Physical Sciences during breaks and at the end of the face-to-face workshops. These chats acted as some sort of support to the teachers, available only in face-to-face workshops. This is because each time the teacher(s) approached the facilitator, they would ask them questions about some of challenges they face as they teach learners. The opportunities to chat with the facilitators helped the teachers in getting the required assistance or support, especially novices and off-field teachers. However, these chats were not part of the intervention structure, as such, teachers might not have had sufficient time to engage with the facilitators to address all their concerns. This implies that such support should be formally made available in the intervention. Figure 4 suggests that such support can be made available by using coaching and/or mentorship. The coaching and mentoring places great importance on one-on-one interactions in promoting professional development (Kennedy, 2005).

Although the intervention model did not include coaching and/mentoring to provide teachers with adequate support, thereby promoting professional development, it employed the community of practice model. This support was made available by utilising WhatsApp, where a WhatsApp group was established in this regard. Since this was a group, the community of practice was a collaboration instead of individual support. However, this was not very important as all members could benefit from the group as long as there was active engagement. The issue was that the group was not active at all and used mostly for administrative purposes. As such, it did not provide any support to the teachers. It is the view of this study that this lack of activity in this collaboration group was the result of poor overall active engagement in the intervention.

This study noted that teachers did not actively participate much during the workshops and spent their time listening to the facilitator without actively engaging with the shared information as commonly observed in DBE workshops (Bantwini & King-McKenzie, 2011). They were also not given authentic activities or opportunities to reflect on what they have learned during or after each intervention workshop as Figure 4 suggests. This implies that all models of professional development adopted by the intervention should be carefully structured and utilised to their fullest potential. This indicates that active engagement should be promoted in the established community of practice. This can be achieved by prompting teachers to use the WhatsApp group to reflect their attempts to implement the learnt teaching and learning strategies. As all teachers will be sharing their reflections, they will also be expected to comment on other teachers attempts, providing them with support. Through this approach, other teachers will learn from the shared information and use it to develop their own teaching practice. Therefore, facilitators must make means to initiate and establish active engagement in communities of practice. Teachers must also be given authentic activities to complete to ensure engagement with the workshop content and promote active engagement during the workshop as suggested by Figure 4. Furthermore, facilitators must observe teachers in their lessons and provide them with constructive feedback using the coaching/mentoring model.

This study noted that lack of active engagement, which contributed to poor attendance, may have been caused by lack of relevance and usefulness of the information shared during the workshop. This study found that teachers had topics that they found difficult and would need to be professionally developed on them, shown in Figure 11. However, some of these topics were not addressed during the intervention, such as the topic of electric circuits. Since individuals can professionally develop themselves on fields that are of interest to them (Bandura, 1994) it is t important that intervention aligns with the needs and interests of the teachers. This means that the workshops should be relevant and useful to the teachers, thus, they must be based on areas that the teachers find difficult and challenging for learners to understand, e.g. the Electric Circuits topics that all teachers find challenging, as shown in Figure 11. In addition, active engagement should be promoted to enhance comprehension of the shared information and effectiveness of the intervention.

Furthermore, more time should be spent on each topic, as shown in Figure 4. The intervention only had 16 hours of contact time with the teachers, and therefore less than the research suggested contact time of at least 20 hours. This was largely the result of the time constraints posed by the Grade 12 curriculum. These constraints resulted in more than one topic being addressed per workshop. For example, the Chemical equilibrium topic was taught along with the Rates of Reaction topic within the two hours of workshop six. This duration was not adequate, especially since Chapter Seven has revealed that these teachers are experiencing challenges in teaching Chemistry topics. Rates of Reactions and Chemical equilibrium are Chemistry topics, with the former topic considered not so difficult to teach by the three novice teachers. Due to the limited time spent on these two topics, Mr Brown continued to experience challenges in teaching Chemistry topics, especially Chemical equilibrium to the extent that that he requested another teacher to teach this topic on his behalf after the intervention. This suggests that each topic must be addressed thoroughly with sufficient time. Furthermore, active engagement through authentic activities and reflection must be promoted to ensure that teachers apply what they have learned and share reflections indicating areas that still need development. Therefore, the role of active engagement cannot be downplayed in an intervention as it is fundamental in the learning process.

8.5. SUMMARY OF THE CHAPTER

This chapter has presented the views of the teachers with regards to the effectiveness of the blended professional development intervention workshops in improving their teaching practice. These views were obtained mainly from interviews collected after the teachers had participated in the intervention. Using triangulation of data sources, the interviews were analysed, and four themes were generated – attendance, flexibility, individual support, and active engagement in online and face-to-face workshops. Additional evidence sought was obtained from field notes written during the intervention to support generated meanings per theme. This study has found that these teachers' attendance in online workshops was hindered by the cost of data bundles and poor network coverage. In face-to-face workshops, it was hindered by lack of financial support where teachers had to shoulder the travelling costs. Nevertheless, the teachers found online workshops to be more flexible as they allowed them to attend with their learners.

This study has presented evidence showing that the teachers preferred face-to-face workshops as they provide consultation opportunities. This chapter has revealed that teachers easily get distracted in online workshops causing them to fall asleep and attend to other tasks that are unrelated to the workshop. This is caused by lack of active engagement during the online workshops and lack of relevance and usefulness of the information being shared. Based on these findings, it is the view of this study that the teachers did not have much of a positive view about online workshops compared to face-to-face workshops of the professional development intervention. Implications of each of these findings are presented above in line with improving the effectiveness of the intervention in the future. The next chapter present findings on the changes, or lack thereof, observed in the teaching practices of these teachers.

CHAPTER NINE: INFLUENCE OF THE INTERVENTION ON TEACHING PRACTICE OF NOVICE TEACHERS

9.1. INTRODUCTION

This study aimed to examine the effectiveness of the blended professional development intervention in improving the teaching practice of novice teachers in the rural schools of Mpumalanga province. This involves an understanding of the views of the teachers regarding the blended approach adopted by the intervention, as presented in the previous chapter. The effectiveness of the intervention can also be viewed in terms of changes in the teaching practice of the novice teachers. This involves a comparison of the manner in which the teachers were promoting knowledge building in their lessons before and after participating in the intervention is made. In this chapter, a comparison of the teaching practices of these teachers before and after participating in the intervention is made and emerging findings are presented and discussed with their implications elaborated on. A summary of how data was collected and analysed to determine the changes, or lack thereof, in the teaching practices of these teachers are presented in the next section of this chapter.

9.2. SUMMARY OF THE DATA COLLECTION AND ANALYSIS PROCESS

To determine changes, or lack thereof, in teaching practice, two video recorded lesson observations were conducted *before* the teachers participated in the intervention. Two more video recorded lesson observations were conducted *after* the teachers participated in the intervention. The lesson observations were transcribed and coded using the codes shown in Table 18. The codes were derived from integrating the semantic codes of legitimation code theory (LCT) and knowledge building of pedagogical link making (PLM), as shown in Table 5. In other words, triangulation of frameworks was used to analyse the lesson observations data. Although both frameworks were utilised to analyse the data, the PLM framework was used primarily to code the data, while semantic codes of LCT, compatible with each knowledge building approach of PLM, were used to draw semantic profiles for each observed lesson. These semantic profiles provide visual representations of the approaches used by each teacher to promote knowledge building in their lessons. To corroborate some of the emerging findings from the analysis process, evidence was sought from the field notes as well as interviews. As such, this study used triangulation of data sources in addition to using triangulation of framework to determine changes in the teaching practices of the novice Physical Sciences teachers. The emerging findings are presented below.

9.3. FINDINGS PRESENTATION

9.3.1. Teaching Practice of Mr Brown before the intervention

The figure below shows the semantic profile of Mr Brown's first lesson before participating in the intervention where he was teaching the learners about the factors that affect the rates of reactions. The semantic profile shows the different approaches Mr Jones used to promote knowledge building and the varying semantic code strengths per knowledge building approach.

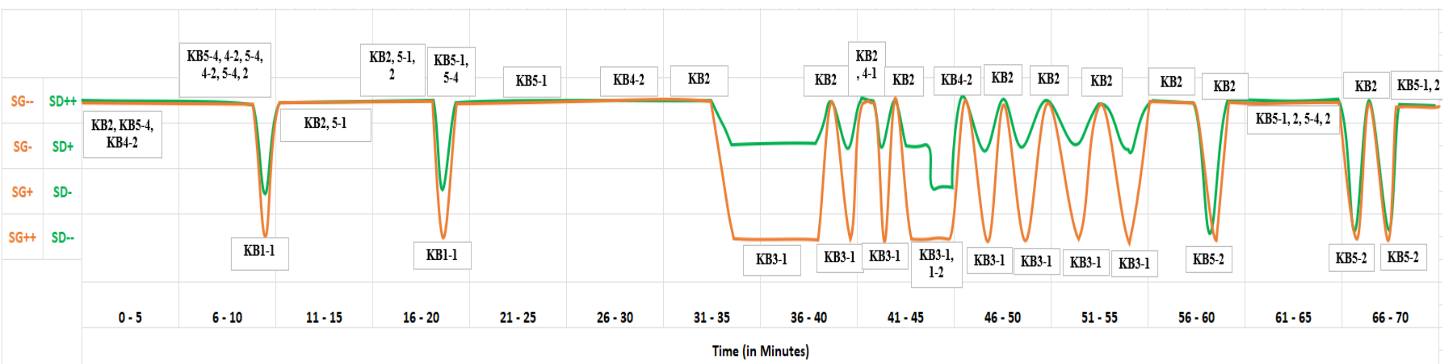


Figure 15: Mr Brown Semantic Density and Gravity Profile - Lesson 1 (Pre-intervention)

Figure 15 above shows that Mr Brown's lesson was largely at a high semantic density strength (SD++), whereby he was making links between: (1) scientific concepts (KB2), (2) different scales and levels of explanation at phenomenological (KB4-1) and theoretical (KB4-2) level, (3) modes of representation using symbols (KB5-1) and chemical equations (KB5-4). When Mr Brown was making the above-mentioned links, the semantic gravity strength remained lowest, at SG--. According to Figure 7 and Tables 3 and 4, when semantic codes are SD++ and SG--, it indicates that Mr Brown was making links between four or more topic-specific abstract concepts and their symbols (chemical equations) to enable comprehensive understanding of the topic content.

While the lesson was largely at SD++ and SG--, Figure 15 shows that there were instances where Mr Brown weakened the semantic density strength from SD++ to SD+. When the semantic density strength was weakened to SD+, Figure 15 shows that Mr Brown was unpacking the content for the learners by making links between scientific explanations and real-world phenomenon using simple phenomenon only in the entire lesson. Figure 15 shows that semantic density strength was further weakened to enable learners' understanding of content through shifts between SD++ and SD-- by making links between modes of representation using pictures (KB5-2) and using integration (KB1-1) to make links between every day and scientific ways of explaining in the 6-10- and 16-20-minutes interval. Mr Brown also used differentiation (KB1-2) in the 41-45 minutes interval to make links between every day and scientific ways of explaining as a way of unpacking the content for the learners, thereby promoting knowledge building. However, integration (KB1-1) and differentiation (KB1-2) were not used significantly in the lesson to unpack the content for the learners as compared to simple phenomenon (KB3-1), as observed with the least number of occurrences.

The weakening and strengthening of semantic codes resulted in the formation of semantic waves of varying ranges. For example, in the 46-55 minutes interval, Mr Brown's lesson has semantic density waves of small ranges from SD++ to SD+ with semantic gravity waves of greatest ranges from SG-- to SG++. Figure 15 shows that these varying semantic waves resulted from Mr Brown shifting from making links between scientific concepts (KB2) to using simple phenomena (KB3-1) to make links between scientific explanation and real-world phenomena. When Mr Brown used pictures (KB5-2) to make links between modes of representation shifting from SD++ and SG--, semantic waves of highest range were formed as observed in the 55-60- and 66-70-minutes intervals. Semantic waves of slightly high ranges were also observed in the semantic density profile in Figure 15 in the 6-10- and 16-20-minutes intervals when Mr Brown was using integration to promote knowledge building. In instances where Mr Brown was not unpacking the content or repacking it, semantic flatlines were formulated. An example of a high semantic flatline is depicted in the 21-30 minutes time interval while a low semantic flatline of semantic gravity is depicted in the 30-40 minutes time interval.

While Mr Brown was able to weaken and strengthen semantic codes throughout his lesson resulting in semantic waves of varying ranges, he did not make such shifts in his second lesson as, shown in the semantic profile below when he was teaching the topic of Rate of Reaction focusing on the mechanism of reaction and of the catalysis.

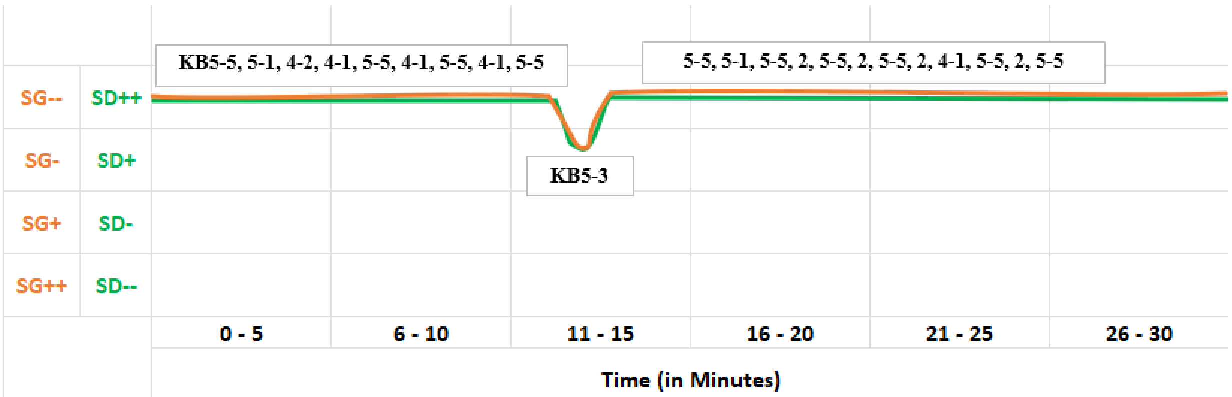


Figure 16: Mr Brown Semantic Density and Gravity Profile - Lesson 2 (Pre-Intervention)

In his second lesson, as shown in Figure 16 above, Brown weakened semantic density strength only once, shifting from SD++ to SD+, resulting in a semantic wave of a small range.. When weakening the semantic density while strengthening semantic gravity, Figure 16 shows that Mr Brown was referring to a diagram (KB5-3) to aid learners' understanding of the content. This unpacking was observed in the 11-15 minutes interval only. This entails that the entire lesson was at SD++, where Mr Brown, as shown in Figure 16, was observed making links between: (1) scientific concepts (KB2), (2) different scales and levels of explanation at phenomenological (KB4-1) and theoretical level (KB4-2), and (3) modes of representation using symbols (KB5-1) and graphs (KB5-5). Thes lesson was taught at a high semantic level, where semantic density is strongest while semantic gravity is weakest, indicating no relation to everyday encounters as links between four or more topic-specific concepts were being made as described in Table 3 and Table 4 of Chapter Three. As such, high semantic flatlines were observed in this lesson, as shown in the 0-10- and 16-30-minutes time intervals.

When comparing Mr Brown's lessons one and two, the two semantic profiles above show that he engaged in unpacking and repacking of scientific content more in his first lesson compared to his second lesson. A summary of the codes used to unpack and repack content is shown in the semantic plane below.

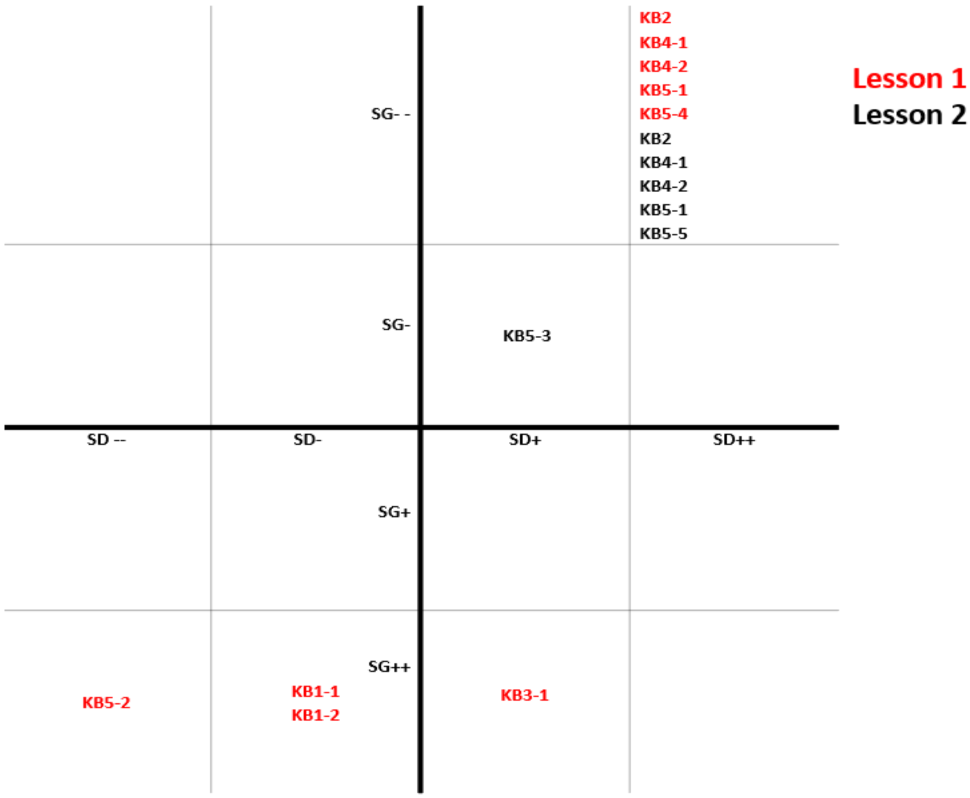


Figure 17: Mr Brown's Semantic plane (Pre-Intervention)

Figure 17 above shows that in both lessons, Mr Brown made links between scientific concepts (KB2); different scales and levels of explanation at phenomenological (KB4-1) and theoretical (KB4-2) level. In both lessons, Mr Brown also used symbols (KB5-1) to make links between modes of representation. In addition to symbols, Mr Brown used chemical equations (KB5-4) in his first lesson while using graphs (KB5-5) in his second lesson. However, both graphs and Chemical equations represent a networked body of knowledge, hence they are at SG-- and SD++ in the semantic plane above similar to links between scientific concepts (KB2) and explanations at phenomenological (KB4-1) and theoretical (KB4-2) level. Hence, they are found in the top right-hand corner of the semantic plane above.

Figure 17 also shows that there was little variation in the number of knowledge building codes used in the second lesson compared to the first one. For example, in addition to the knowledge building codes found in the SG-- and SD++ space on the semantic plane, Mr Brown used a diagram (KB5-3) in his second lesson, which falls at the SD+ and SG- space in the first quadrant of the semantic plane above. This is in contrast to his first lesson where Mr Brown used (a) pictures (KB5-2) to make links between modes of representation; (b) integration (KB1-1) and differentiation (KB1-2) to make links between every day and scientific ways of explaining; and (c) simple phenomena to make links between scientific explanations and real-world phenomena. As such, the knowledge building codes of the second lesson are found in the first quadrant only while those of the first lesson are spread across the third and fourth quadrant in Figure 17 above. This entails that Mr Brown made numerous shifts in his first lesson unpacking and packing content for the learners while such a shift was made only once in this second lesson. Thus, his first lesson comprised of numeral occurrences of both SD++ to SD-- and SG-- to SG++ while his second lesson consisted of one shift between SD++ to SD+ and SG-- to SG-.

9.3.2. Teaching Practice of Mr Brown Post-Intervention

Figure 18 below shows the semantic profile of Mr Brown's first lesson after participating in the intervention where he was teaching about electric circuits. The semantic profile shows the different approaches used by Mr Brown to aid knowledge building and the varying semantic code strengths per knowledge building approach.

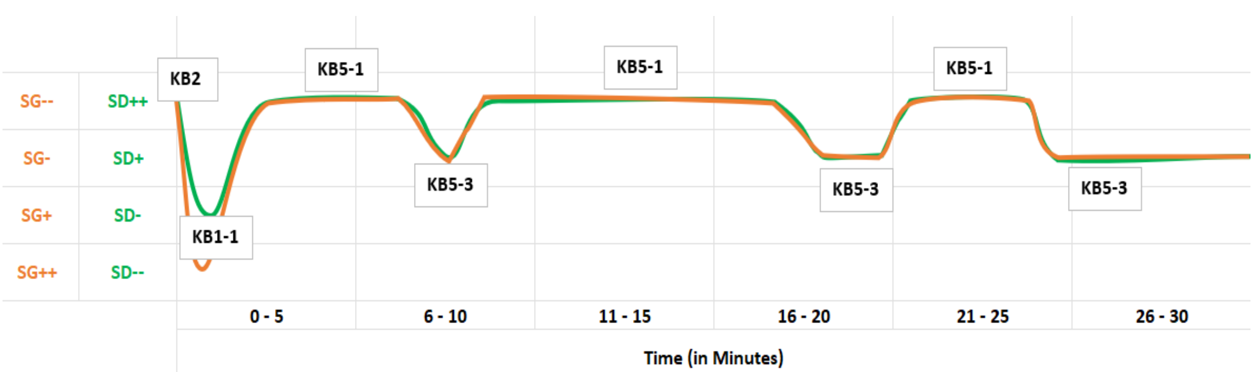


Figure 18: Mr Brown Semantic Density and Gravity Profile - Lesson 1 (Post Intervention)

Figure 18 above shows that Mr Brown did engage in the unpacking of content in this lesson, although that was not frequent as in his first lesson before the intervention. For example, Figure 18 shows that Mr Brown started the lesson by making links between scientific concepts (KB2). He proceeded to unpack the concepts using integration (KB1-1) to make links between every day and scientific ways of explaining, thereby shifting from SD++ and SG-- to SD- and SG+. Mr Brown then repacked the concepts using symbols (KB5-1) to make links between modes of representation, shifting from SD- and SG+ to SD++ and SG--. Thereafter, Mr Brown would unpack the concepts referring to diagrams (KB5-3) and repack the concepts using symbols (KB5-1) in the remainder of the lesson. He did not do this during the 11-15 minutes interval where he continued to use symbols without unpacking them, thereby weakening semantic density and strengthening semantic gravity.

It is important to note that Mr Brown made links between scientific concepts (KB2) only once in his lesson similar to integration (KB1-1) used to unpack the scientific concepts. The rest of the lesson was spent largely using symbols (KB5-1) to make links between modes of representation, with one occurrence of unpacking using diagrams (KB5-3) per time interval (except in the 11-15 minutes interval), resulting in the formation of semantic strength of small ranges. Thus, the lesson produced numerous semantic flatlines. However, not all the observed semantic flatlines were high, as those in the 11-15-minutes time interval, some were low within the SG- and SD+ range, resulting from the continuous use of diagrams to unpack content as observed in the 26-30-minutes time interval of Figure 18 above. The shifts between the varying strength ranges of semantic gravity and density made by Mr Brown as he was promoting knowledge building in his second post-intervention lesson as he was teaching Newton's Laws are shown below.

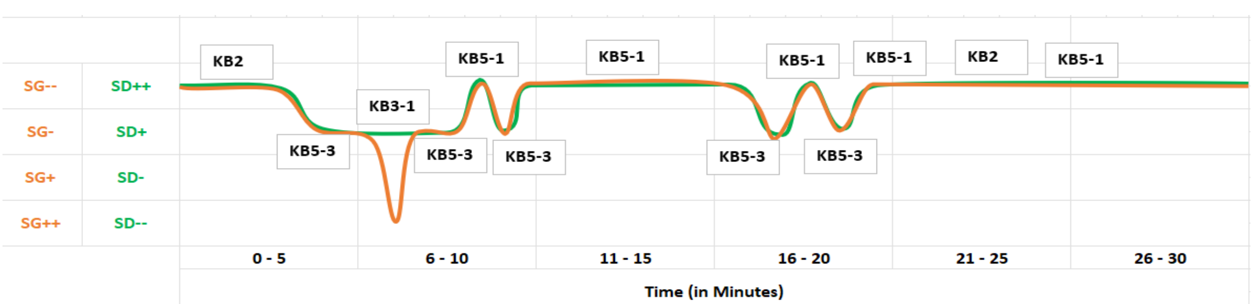


Figure 19: Mr Brown Semantic Density and Gravity Profile - Lesson 2 (Post Intervention)

Just like during the first lesson, Mr Brown used symbols to create links between modes of representation. In lessons 1 and 2, he made links between scientific concepts (KB2). However, instead of making a single link between scientific concepts (KB2), three instances were noted in his second lesson. Mr Brown also used diagrams (KB5-3), during his lesson, just like he did during first lesson, to make links between modes of representation, thereby weakening semantic density from SD++ to SD+ while strengthening semantic gravity from SG-- to SG-. When Mr Brown was unpacking the content for the learners, shifting from the SD++ and SG—range to the SD+ and SG- range, semantic waves of small ranges were formed.

Another semantic wave of highest semantic gravity range is noted in the semantic profile above when Mr Brown was using simple phenomena (KB3-1) to make links between scientific explanations and real-world phenomena in the 6-10 minutes interval. However, since only four semantic waves were identified in the entire semantic profile of Mr Brown, t the rest of the lesson formed semantic flatlines. The resulting semantic flatlines were high resulting from linking scientific concepts and using symbols to make links between modes of representation, which resides at the SD++ and SG-- range. A low semantic density flatline is also noted between the 0-10 minutes interval, where Mr Brown was shifting between using simple phenomenon (KB3-1) and diagrams (KB5-3) to promote knowledge building in his lesson. The similarities and differences between the two lessons of Mr Brown are illustrated in Figure 20 below.

Figure 20 shows that during both lessons, four different approaches were used to promote knowledge building. In both lessons, Mr Brown made links between scientific concepts (KB2) and used symbols to make links between modes of representations at the SD++ and SG-- range. Diagrams were also used in both lessons to promote knowledge building by unpacking it as it occurs in the SD+ and SG- range in the first quadrant of the semantic plane above. The two lessons vary in the used SG++ range where Mr Brown used integration (KB1-1) in the first lesson with semantic density at the SD- range in the third quadrant of Figure 20 while using simple phenomena (KB3-1) in the second lesson with semantic density at the SD+ range in the fourth quadrant of Figure 20. At glance, both lessons had instances of unpacking and repacking, resulting in the formation of semantic waves of varying ranges. However, Figure 18 and Figure 19 show that semantic flatlines were also observed as unpacking and repacking instances were limited.

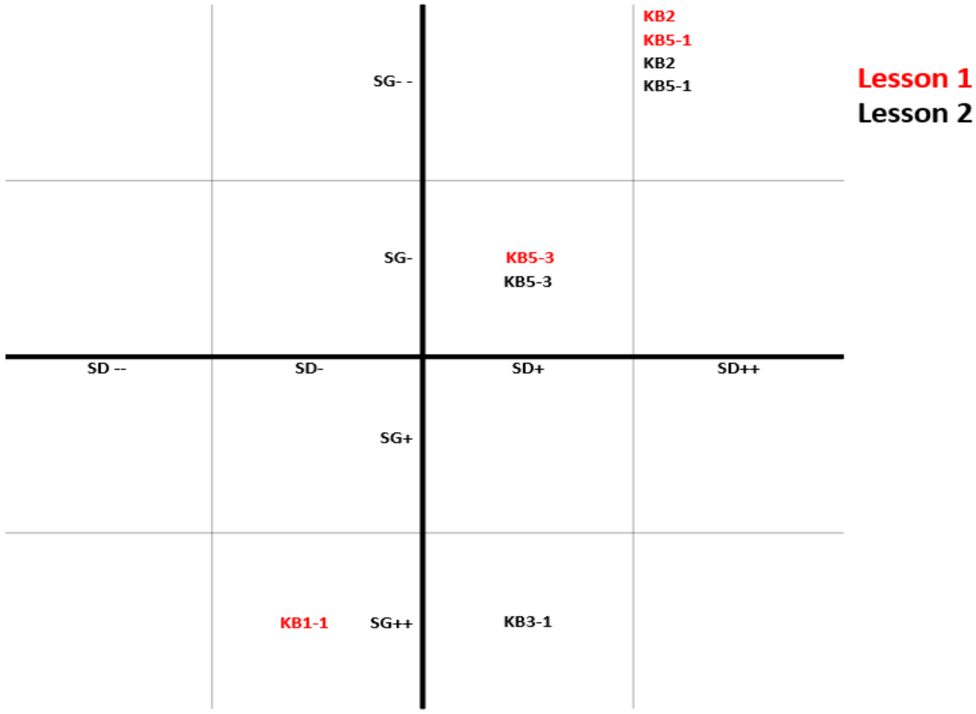


Figure 20: Mr Brown semantic plane (Post Intervention)

Although one type of knowledge building approach per post intervention lesson was used to unpack the content, several semantic waves were formed in these post intervention lessons compared to the second pre-intervention lesson, as shown in Figure 16. In his second pre-intervention lesson, Mr Brown unpacked content once in the entire lesson. This study acknowledges that the lack of numerous instances of weakening of semantic density and strengthening of semantic gravity in post intervention lessons may be the result of the content having been taught to the learners from lower grades and earlier in Grade 12 as these lesson observations were conducted after the preliminary examination had been written. As such, the lessons were more of a revision than an introduction of new content. However, the lack of numerous cases of unpacking and repacking in the second pre-intervention lesson reaffirms the identified challenge of teaching Chemistry in Chapter Seven (under the content representation sub-theme of Classroom efficacy), with a particular focus on using analogies and examples from everyday life. As shown in Figure 17, Mr Brown used a single scientific diagram to unpack the content in his second pre-intervention lesson. However, none of the teachers indicated that the topic of Rate of Reactions was challenging in Figure 11 (Chapter Four, section 4.3.2).

The following extract by Mr Jones shows that there is a challenge in teaching and learning the topic of Rates of Reaction as learners are not performing well on this topic.

> *Not necessarily electrochemistry, but rates of reaction. They normally don't answer that question. They think it's difficult.*

In the extract above, Mr Jones explains that learners tend to skip questions on Rate of Reactions, resulting in poor performance. It is important to note that teachers' lack of awareness of the experienced challenges in teaching and learning this topic may be an illusion created by the introduction of the topic, which focuses on the factors that influence the rate of reaction. The factors that affect rates of reactions are easily relatable to everyday life encounters, hence numerous semantic waves of varying ranges were observed in Mr Brown's first lesson. However, as one proceeds with the topic, it becomes more abstract, and more challenging to relate into everyday encounters as observed during Mr Brown's second lesson. Failure to unpack and repack the content for the learners may hinder understanding, causing learners not to perform well on this topic.

In short, the semantic profiles and semantic planes of Mr Brown do not show any change in teaching practice, especially in the codes used to unpack and repack content. In both pre and post intervention lessons (one or both lessons per data set), Mr Brown made some useful links between every day and scientific ways of explaining either using integration (KB1-1) and/or differentiation (KB1-2), although it largely involved simplification of non-technical terms. He also made links between scientific explanations and real-world phenomena using simple phenomena (KB3-1). He used diagrams (KB5-3) to make links between modes of representation. The codes of SD++ and SG-- vary based on the nature of content. For example, the second lesson requires the use of graphs while the first lesson required the use of chemical equations, although the use of symbols was common in both lessons. Therefore, based on presented evidence, a lack of change in teaching practice was observed in Mr Brown lessons.

9.3.3. Teaching Practice of Mr Jones - Pre-Intervention

Figure 21 below shows the semantic profile of Mr Jones' first lesson before participating in the intervention where he was teaching the learners the topic of Acids and Bases with a focus on acid and base models, weak and strong acids and bases, conjugate acid-base pairs, water ionisation, and pH scale. The semantic profile shows the different approaches Mr Jones used to promote knowledge building and the varying semantic code strengths per knowledge building approach.

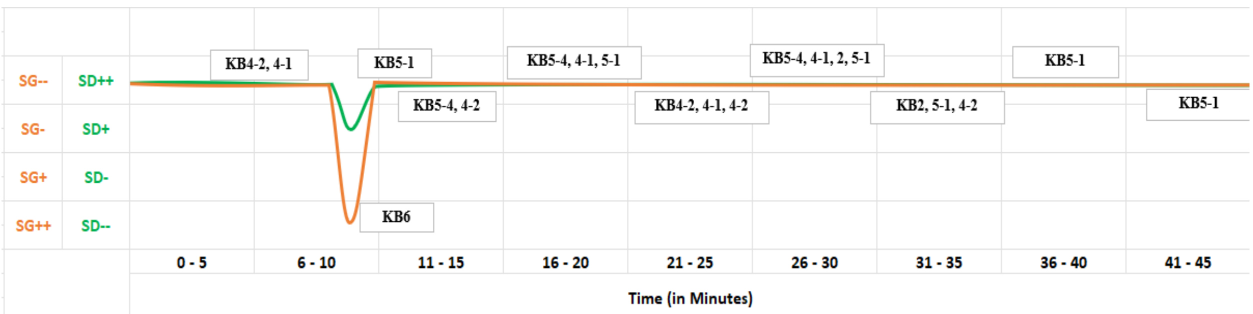


Figure 21: Mr Jones Semantic Density and Gravity Profile - Lesson 1 (Pre-Intervention)

Figure 21 above shows that Mr Jones first lesson consisted largely of high semantic flatlines as seen in the 16-45 minutes interval, for example. In these semantic flatlines, as shown in Figure 21, Mr Jones made links between (a) scientific concepts (KB2), (b) different scales and levels of explanation at phenomenological (KB4-1) and theoretical (KB4-2) level, and (c) modes of representation using symbols (KB5-1) and chemical equations (KB5-4). Since the high semantic flatlines are at the SG-- and SD++ range, there was not much unpacking and repacking of content in the lesson. Only one instance of unpacking was observed during the entire lesson. As seen in Figure 21, Mr Jones unpacked the content once by making links between analogous cases (KB6). Due to this unpacking instance, a semantic gravity wave of highest range and a semantic density wave of lowest range were produced, as shown in the 6-10 minutes interval. This was also observed during Mr Jones' second lesson as he was continuing with the topic of Acids and Bases, with a focus on pH calculations, as depicted in Figure 22 below.

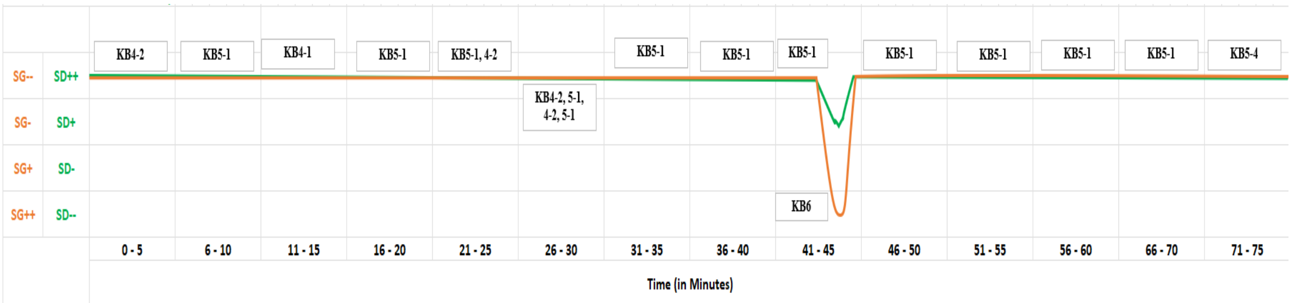


Figure 22: Mr Jones Semantic Density and Gravity Profile - Lesson 2 (Pre-Intervention)

Figure 22 shows that Mr Jones varied the semantic gravity strength only once in his entire lesson. This change in semantic gravity strength is observed in the 41-45 minutes interval. This change in strength resulted from the use of analogies, where Mr Jones made links between analogous cases (KB6). Since the semantic gravity strength was increased from SG-- in this instance resulting in the formation of a semantic wave of greatest range, there was also a shift in semantic density strength from SD++ to SD+ resulting in the semantic density wave of the least range. The rest of the lesson was at the SD++ and SG-- range resulting in the formation of semantic flatlines as noted in the 0-40- and 46-75-minutes interval. This shows that the lesson consisted of abstract concepts that were not simplified by occasional weakening of semantic density and strengthening of semantic gravity. Mr Jones spent his time during the lesson making links between different scales and levels of explanation at phenomenological (KB4-1) and theoretical (KB4-2) levels, and modes of representation using symbols (KB5-1). Mr Jones did not make links between scientific concepts (KB2) in this lesson, as he had done in his first lesson. An overview of the two lessons is presented below.

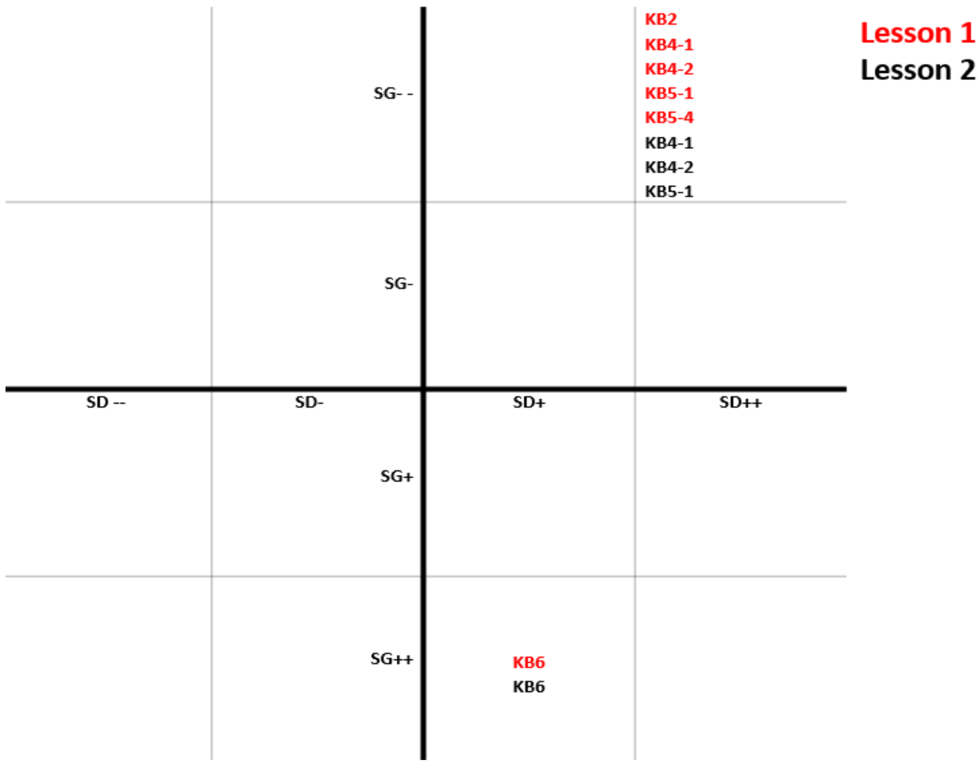


Figure 23: Mr Jones Semantic plane (Pre-Intervention)

Figure 23 shows that in both lessons, Mr Jones made links between different scales and levels of explanation at phenomenological (KB4-1) and theoretical (KB4-2) level, modes of representation using symbols (KB5-1), and analogous cases (KB6). In contrast to the second lesson, the first lesson, also had links between scientific concepts (KB2), and between modes of representations using chemical equations (KB5-4). However, both lessons did not involve numerous instances of unpacking and repacking as only one per lesson was observed, whereby analogous cases (KB6) were used to promote knowledge building and enhance learners' understanding.

9.3.4. Teaching Practice of Mr Jones Post-Intervention

The figure below shows the semantic profile of Mr Jones' first lesson after participating in the intervention where he was teaching the learners the topic of Chemical equilibrium. The semantic profile shows the different approaches Mr Jones used to promote knowledge building and the varying semantic code strengths per knowledge building approach.

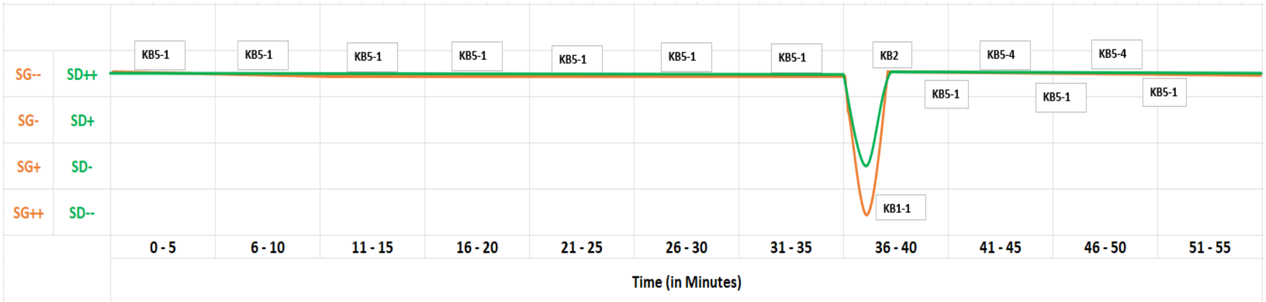


Figure 24: Mr Jones Semantic Density and Gravity Profile - Lesson 1 (Post-Intervention)

Figure 24 shows that Mr Jones changed the strength of semantic gravity and density once only throughout his lesson, from SG-- to SG++ and SD++ to SD-, during the 36-40 minutes time frame. In this time interval, Mr Jones unpacked the concepts using integration (KB1-1) to make links between very day and scientific ways of explaining and repacked it by making links between scientific concepts (KB2). Since the unpacking was observed only once, the rest of the lesson was taught at the SG-- and SD++ range. Thus, producing the observed high semantic gravity and density flatline, shown in Figure 24. Figure 24 demonstrates that the produced high semantic flatlines in the 0-35 minutes interval resulted from Mr Jones using symbols (KB5-1) only to make links between modes of representation. In the remainder of the lesson, the semantic flatlines were the results of making links between modes of representation, where Mr Jones was shifting between using symbols (KB5-1) and chemical equations (KB5-4). This lesson resembles the pre-intervention lessons in Figure 21 and Figure 22 where semantic density was weakened only once while increasing the semantic gravity strength in the entire lesson. However, the second post intervention lesson focusing on Organic Chemistry was quite different from all his observed lessons as shown in the figure below.

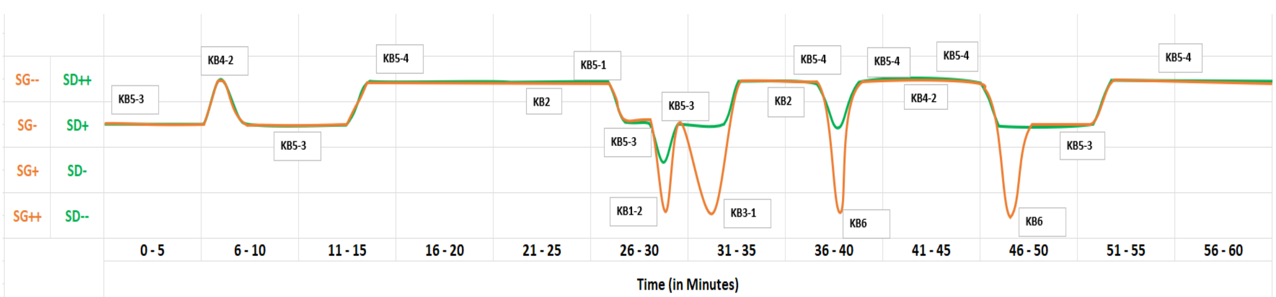


Figure 25: Mr Jones Semantic Density and Gravity Profile - Lesson 2 (Post-Intervention)

Figure 25 shows that Mr Jones started the lesson at SD+ and SG- range, whereby he used diagrams to promote knowledge building. After 0-5 minutes interval, Mr Jones packed the content for the learners shifting it to SD++ and SG—by making links between different scales and levels of explanation at phenomenological level (KB4-20). He then unpacked the concepts by shifting to SG- and SD+ using diagrams (KB5-3).

Using chemical equations (KB5-4), Mr Jones repacked the content for the learners shifting to SD++ and SG—range. At SD++ and SG—range, as shown in Figure 25 above, Mr Jones made links between scientific concepts and used symbols to make links between modes of representation. Thereafter, he unpacked the content using diagrams (KB5-3) and further unpacked the concepts using differentiation (KB1-2). After differentiation, Mr Jones repacked the concepts using diagrams (KB5-3) and unpacked it using simple phenomena (KB3-1) to make links between scientific explanations and real-world phenomena. The content was then repacked by making links between scientific concepts (KB2) followed by using chemical equations (KB5-4). After chemical equations, there was some unpacking where analogous cases (KB6) were used to promote knowledge building. Using chemical equations and complex phenomena to make links between scientific explanations and real-world phenomena, the knowledge was repacked, and unpacked using analogous cases (KB6) once again. Thereafter, the knowledge was repacked by using diagrams (KB5-3) and further repacked using chemical equations (KB5-4).

In between some of the unpacking and repacking instances, semantic flatlines were observed. Some of these semantic flatlines were high, residing at SD++ and SG-- range as shown in 16-25- and 41-45-minutes intervals. The low semantic flatlines were residing at the SD+ and SG- range as shown in the 0-5 minutes interval. This entails that the repacking and unpacking did not always produce a smooth semantic wave as in 36-40 minutes interval. In some instances, down and/or up escalators, as shown in Figure 9, were observed when unpacking or repacking was taking place which were then followed by semantic flatlines. An example of the noted up-escalators is shown in the 11-15- and 5-55-minutes intervals where Mr Jones was using chemical equations (KB5-4) to repack the knowledge, shifting from using diagrams (KB5-3) in the SD+ and SG+ range. A down escalator is observed from the 26-30 minutes interval where Mr Jones was unpacking the content from using symbols (KB5-1) to using diagrams (KB5-3), shifting from SD++ and SG-- to

SD+ and SG+ range. These down and up escalators were also observed in some of Mr Brown's lessons, particularly the post intervention lessons. An overview of Mr Jones' lessons is depicted in Figure 26 below.

Figure 26 shows that Mr Jones used different types of approaches to promote knowledge building, which resulted in numerous instances of repacking and unpacking. To unpack, Figure 26below shows that Mr Jones used diagrams (KB5-3), simple phenomena (KB3-1), differentiation (KB1-2), and analogies/analogous cases (KB6). This was in contrast to his first lesson where only one instance of unpacking was noted resulting from the use of integration (KB1-1) to promote knowledge building. This indicates that his first post intervention lesson was similar to his pre-intervention lessons whereby one instance of unpacking was noted in the entire lesson. It is important to note that the use of diagrams is unavoidable in the Organic Chemistry topic. Therefore, it cannot be compared with any other topic in Chemistry which has different requirements. Hence, it should not be surprising to see it being used quite more frequent in this lesson compared to the other lessons/topics.

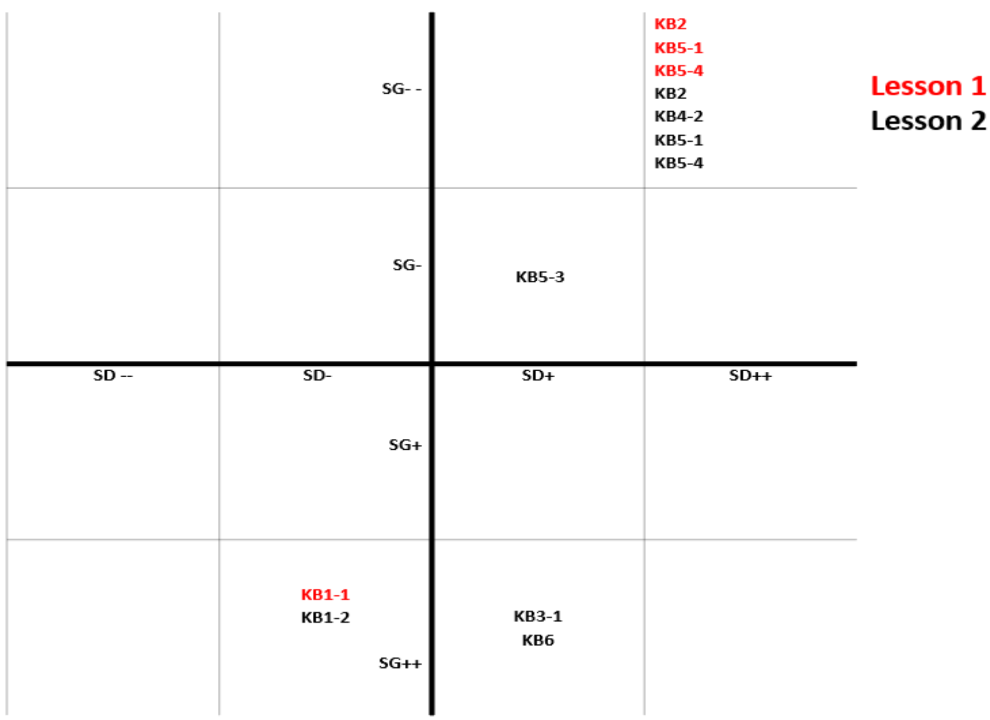


Figure 26: Mr Jones Semantic plane (post-intervention)

However, similarity in Mr Jones' first post lesson intervention and his pre-intervention lessons is puzzling because the Chemical Equilibrium topic was addressed during the intervention. The topic of Chemical equilibrium was taught to the teachers in Workshop 6 during the intervention, as shown in Table 6 (Chapter Four). During this intervention, Table 22 (Chapter Eight) shows that Mr Jones was in attendance. Therefore, the lack of improvement in the teaching practice of Mr Jones in this topic may be the result of the workshop not being sufficient for his development as it was combined with the topic of Rates of Reactions and addressed within two hours. It could also be that Mr Jones was preoccupied, trying to listen to learners' questions and asking them on their behalf as he had revealed that he attended that session with his learners. As such, he did not have sufficient time to listen to the facilitator and participator to enhance his own knowledge about the topic. The observed changes in the topic of Organic Chemistry cannot be attributed to the intervention as the field notes reveal that he was absent during Workshop 7 and 8 which was held on the 2nd of October 2020. Although Mr Jones did not teach the same topic during his post intervention lesson observations, the similarity in the manner he taught his first post intervention lesson, and the pre-intervention lessons show that there was lack of change in teaching practice after participating in the intervention. In other words, Mr Jones, similar to Mr Brown, has not benefitted anything from the intervention in terms of teaching Chemistry such that it is relatable by using analogies and examples from everyday encounters.

Importantly, Mr Jones seemed to have started making links between every day and scientific ways of explaining during his post lessons intervention. This is because instances of integration and/or differentiation are not included in Figure 23, thereby indicating that this knowledge building approach was not used. This is in contrast to the great awareness of the language issues that Mr Jones displayed during the pre-intervention interview. The lack of use of differentiation and integration in his pre-intervention lessons indicate that he was not aware of this issue. This is because his pre-intervention lessons were conducted on the topic of Acids and Bases, a topic that is closely related to everyday life encounters. Thus, he should have used differentiation and integration in this topic, particularly in the first pre-intervention lesson, which was an introductory lesson to Acids and Bases, drawing on everyday life experiences. The use of this knowledge building approach may have been induced by the teacher's reflection on interview questions as differentiation and integration were explicitly explained since this language issue was not addressed during the intervention workshops.

9.3.5. Teaching Practice of Mr Smith Pre-Intervention

In Figure 27below, the semantic profile of Mr Smith's first lesson before participating in the intervention where he was teaching the learners the topic of Momentum. The semantic profile shows the different approaches Mr Smith used to promote knowledge building and the varying semantic code strengths per knowledge building approach.

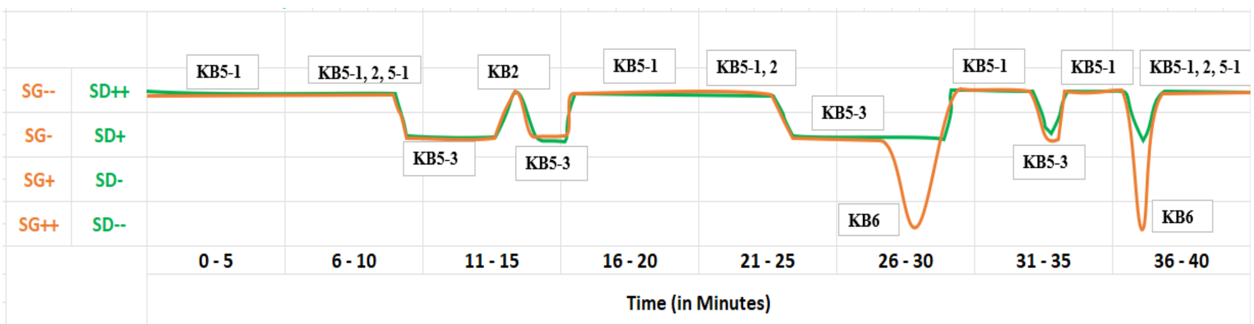


Figure 27: Mr Smith Semantic Density and Gravity Profile - Lesson 1 (Pre-Intervention)

Figure 27 shows that Mr Smith started his lesson in the SD++ and SG-- range and would occasionally decrease the semantic density strength from SD++ to SD+ during the lesson. During these occasional decreases in semantic density strength, Figure 29 indicates that Mr Smith was making links between modes of representation using diagrams (KB5-3), semantic gravity remained at the SG- range. These resulted in small range semantic waves, as shown in the 31-35 minutes range, for example. However, up and down escalators were observed in the lesson as Mr Smith was unpacking the content using diagrams. An example of the down escalator is shown in the 6-10- and 21-25-minutes intervals while that of up escalator is noted in the 16-20 minutes interval. Low semantic flatlines are also observed where Mr Smith was observed to be spending a lot of time in the SD+ and SG- range, using diagrams as shown in the 11-15- and 21-25-minutes interval. High semantic flatlines are noted in the SG-- and SD++ range, where Mr Smiith was observed making links between scientific concepts (KB2) and using symbols (KB5-1) to promote knowledge building.

In addition to using diagrams (KB5-3) to unpack the content for the learners, the figure above shows that Mr Smith also used analogous cases (KB6). Two instances of analogues cases were noted in the lesson. These instances depict semantic gravity wave of greatest range as the strength shift from SD+ in the 26-30 minutes interval and SG++ in the 36-40 minutes interval to SG++. The figure below shows the shifts made by Mr Smith in his second lesson as he was making the pedagogical links to promote knowledge building of the Electric Circuits topic.

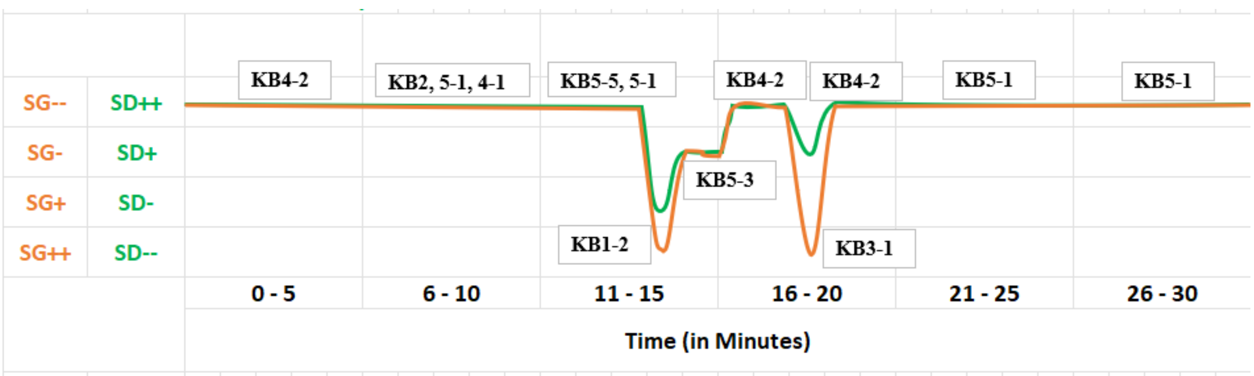


Figure 28: Mr Smith Semantic Density and Gravity Profile - Lesson 2 (Pre-Intervention)

Figure 28 shows that Mr Smith's second pre-intervention lesson was largely at the SD++ and SG— range. This is because Mr Smith was largely making links between (a) scientific concepts (KB2), (b) different scales and levels of explanation at phenomenological (KB4-1), and theoretical (KB4-2) level, and (c) modes of representation using symbols (KB5-1). Due to these knowledge building approaches being at high semantic density and lowest semantic gravity, high semantic flatlines were noted. These high semantic flatlines are well noted in the 0-10- and 21-30-minutes intervals. This indicates that the lesson largely comprised of a network of abstract concepts with limited instances of knowledge being associated with everyday encounters.

The noted instances of knowledge being associated with everyday encounters are found in the 11-15- and 16-20-minutes intervals, whereby Mr Smith was unpacking the concepts for the learners, resulting in the formation of two semantic waves. In the 11-15 minutes interval, Mr Smith used differentiation (KB1-2) and simple phenomena (KB3-1) in the 16-20 minutes interval. Figure 28 above shows that Mr Smith used diagrams to repack the concepts after unpacking using differentiation, shifting the semantic codes from SD- and SG++ to SD+ and SG-. From SD+ and

SG- Figure 28 further shows that repacking was done, thus shifting the semantic range to SD++ and SG-- by making links between different scales and levels of explanation theoretical (KB4-2) level. This repacking produced an up escalator. Figure 29below shows a semantic plane of knowledge building codes used by Mr Smith in his lessons before participating in the intervention.

Figure 29 below shows that Mr Smith had more knowledge building approaches variation in his second lesson compared to his first lesson. For example, in the SD++ and SG-- range, only two knowledge building approaches were used during the first lesson and five in the second lesson. Nevertheless, the following knowledge building approaches were common in both lessons: making links between scientific concepts (KB2) and using symbols (KB5-1) as well as diagrams (KB5-3) to make links between modes of representation. In addition to the knowledge building approaches outlined above, the second lesson also used simple phenomena (KB3-1) and differentiation (KB1-2) to unpack the content for the learners while the first lesson utilised analogous cases (KB6).

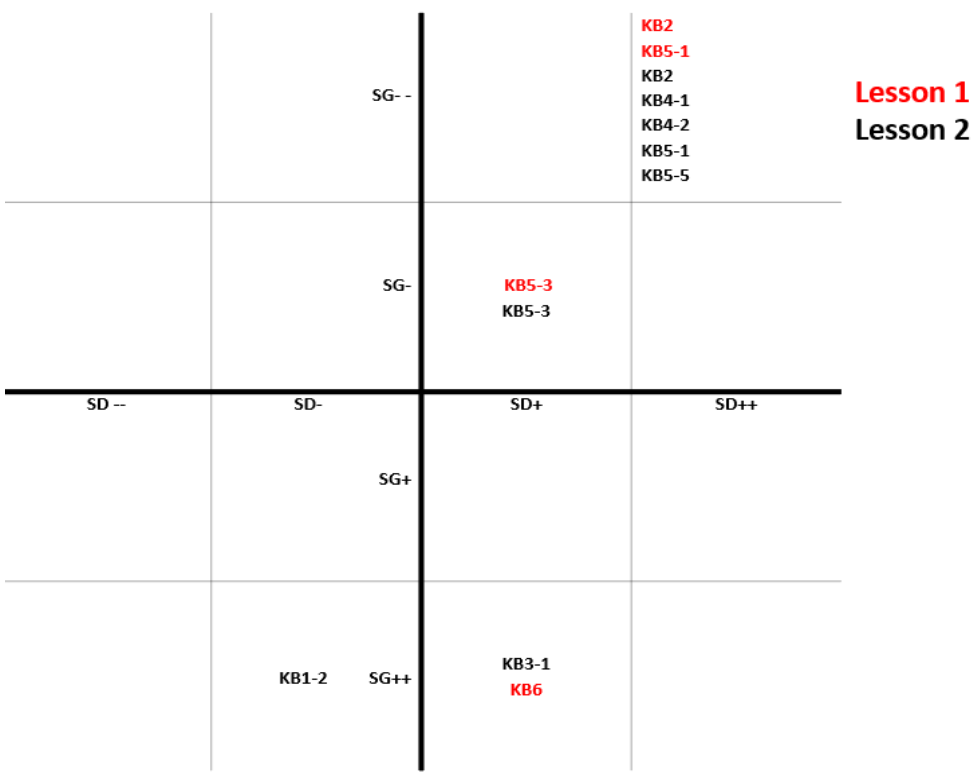


Figure 29: Mr Smith Semantic plane (Pre-Intervention)

9.3.6. Teaching Practice of Mr Smith Post-Intervention

Figure 30 below provides the semantic profile of Mr Smith's first lesson after participating in the intervention where he was teaching the learners the topic of Photoelectric effect. The semantic profile shows the different approaches Mr Smith used to promote knowledge building and the varying semantic code strengths per knowledge building approach.

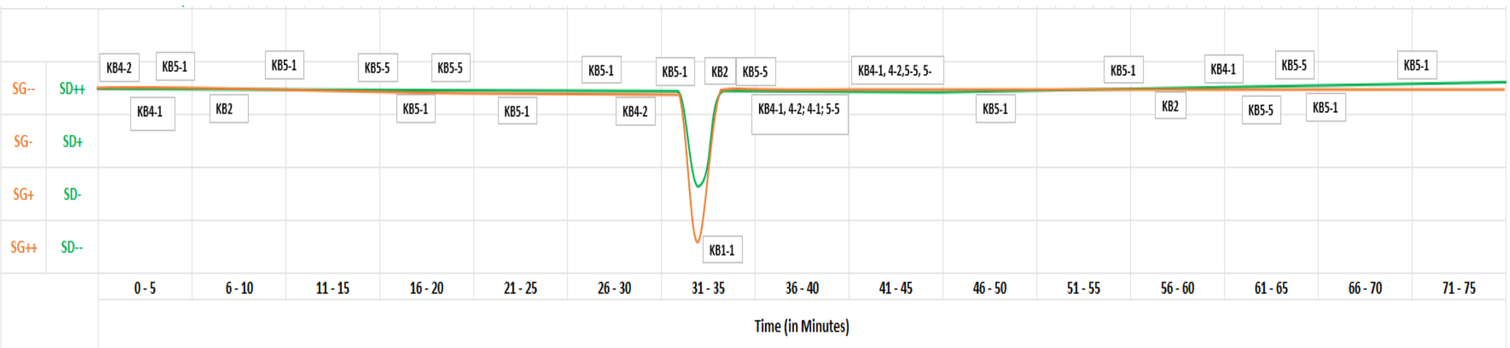


Figure 30: Mr Smith Semantic Density and Gravity Profile - Lesson 1 (Post-Intervention)

Figure 30 shows that Mr Smith's lesson consisted largely of high semantic flatlines on the SD++ and SG-- range. The high semantic flatlines resulted from Mr Smith making links between (a) scientific concepts, (b) different scales and levels of explanation at phenomenological (KB4-1) and theoretical (KB4-2) level, (c) modes of representation using symbols (KB5-1) and graphs (KB5-5). Although the lesson was mostly at the SD++ and SG-- range, an instance of weakened semantic density and strong semantic gravity was observed in the 31-35 minutes interval. In this instance, Mr Smith shifted from the SD++ and SG-- range to the SD- and SG++ by using integration (KB1-1) to make links between every day and scientific ways of explaining. The use of integration resulted in the formation of a semantic wave, as shown in Figure 30 above.. In other words, the lesson consisted of abstract network of concepts with only one instance where these concepts were unpacked using integration (KB1-1). Figure 31below shows the shifts made by Mr Smith in his second lesson as he was making the pedagogical links to promote knowledge building during the Doppler effect topic.

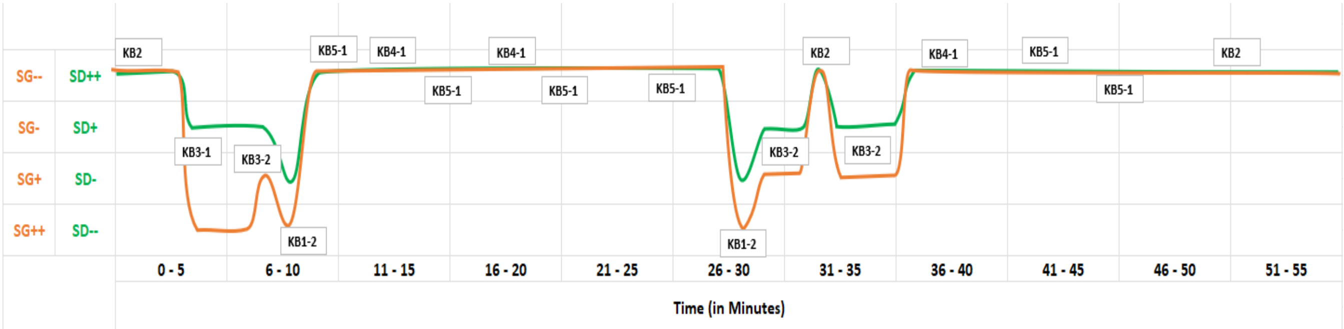


Figure 31: Mr Smith Semantic Density and Gravity Profile - Lesson 2 (Post-Intervention)

Figure 31 above shows that most of the time during the lesson was spent at the SD++ and SG-- range. As a result, high semantic flatlines of strong semantic density and weak semantic gravity are observed in this range in the 11-25- and 36-50-minutes intervals. In the depicted high semantic flatlines, the Figure 31shows that Mr Smith was making links between scientific concepts (KB2), different scales and levels of explanation at phenomenological level (KB4-1), and modes of representation using symbols (KB5-1). There are also instances of low semantic flatlines, as shown in the 31-35 minutes interval, in the SD+ and SG- to SG++ ranges. In the low semantic flatlines, Mr Smith was using simple phenomena (KB3-1) and complex phenomena (KB3-2) to make links between scientific explanations and real-world phenomena.

Besides the semantic flatlines mentioned above, there are also two instances where semantic waves were formed. These instances are found in the 6-10- and 26-30-minutes interval where the semantic range was SD- and SG++. In this range, Mr Smith was using differentiation (KB1-2) to make links between every day and scientific ways of explaining. The resulting semantic waves and low semantic flatlines are an indication that Mr Smith was unpacking and repacking the content for the learners, promoting knowledge building. This is inclusive of the noted up-escalator in the 36-40 minutes interval, where Mr Smith was repacking the content, shifting from SD+ and SG- to SD++ and SG-- by using simple phenomena (KB3-1) to promote the conceptualisation of the knowledge. The figure below provides an overview of the knowledge building approaches used by Mr Smith in his lessons after participating in the intervention.

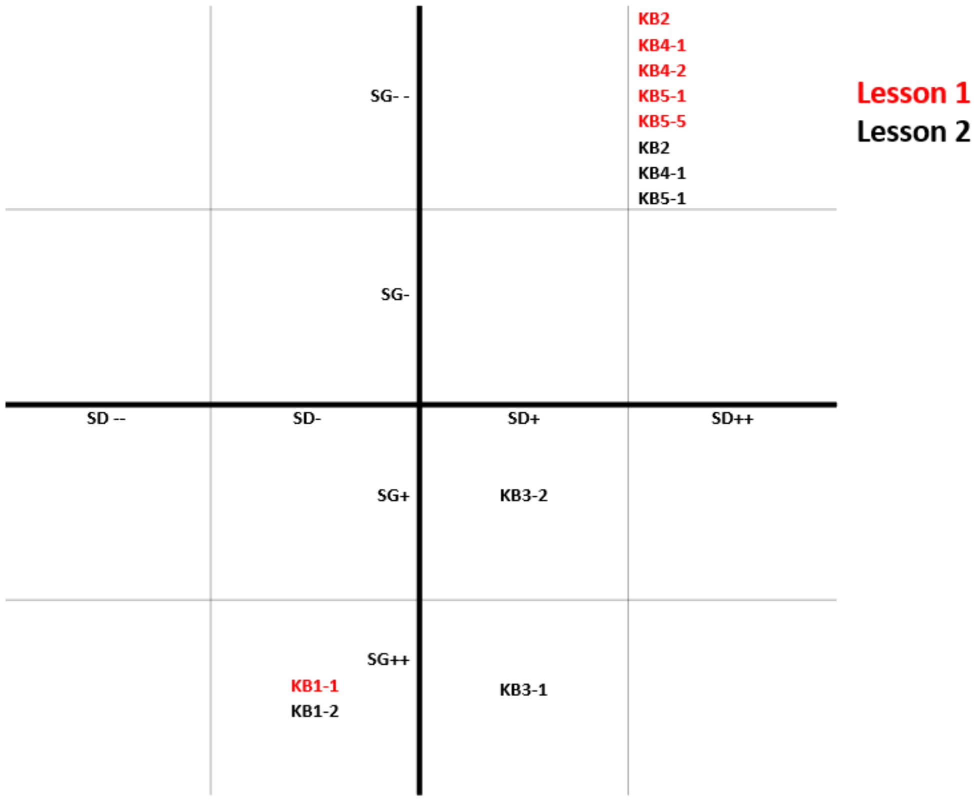


Figure 32: Mr Smith Semantic plane (post-intervention)

Figure 32 above shows a great variation in the knowledge building approaches used during the second lesson compared to the first lesson, indicating that Mr Smith engaged in various approaches to unpack knowledge for the learners. These variations are similar to those observed in the second pre-intervention lesson. However, diagrams (KB5-3) and analogous cases (KB6), used in pre-intervention lesson(s) were not used to unpack the content in post intervention lessons. However, instead of simple phenomena, complex phenomena (KB3-2) were used in the second post intervention lesson to unpack the content, as shown in Figure 32 above. Links between every day and scientific ways of explaining were made using only differentiation in the second post intervention lesson while both differentiation and integration were used in pre-intervention lessons, as shown earlier in Figure 29. It is important to note that the outlined differences between the lessons in terms of knowledge building approaches are influenced by the nature of the topic, for example, the use of diagrams instead of chemical equations in lessons about Momentum and Electric Circuits.

Figure 32 also shows that both lessons of Mr Smith had semantic flatlines with the first lesson resembling Mr Jones' first three lessons (two pre-intervention and first post intervention lesson) and Mr Brown's second pre-intervention lesson. These lessons resemble each other because only one instance of unpacking was observed in all of them. The observed lack of frequent unpacking in the first post intervention lesson can be attributed to the abstract nature of the topic. Photoelectric effect is similar to Chemistry topics because its content refers to phenomena that is beyond the reach of a naked eye, at microscopic level. Thus, the topic may be challenging to teach by any of these teachers, similar to Chemistry topics, as they expressed their need for development in coming up with analogies and examples from everyday life as a way to unpack the Chemistry content. This entails that the teaching practices of these teachers in Chemistry has not changed after participating in the intervention. It also highlights the importance of planning, which gives the opportunity to think carefully about analogies and examples from everyday life.

The lack of change in Chemistry teaching practice, as indicated by the lack of numerous unpacking and repacking instances, would not have been improved by the attendance of all workshops. Mr Smith did not attend all the workshops, particularly those focused on Physics topics, except for Workshop 7 which was combined with Workshop 8. This is because the Chemistry-like topic of Photoelectric Effect topic was not addressed during the intervention, and therefore, no guidance was provided on how they can enhance learning on this topic. This is also evident in the case of Mr Jones and Mr Brown where they attended quite a number of workshops compared to Mr Smith, yet their teaching practice did not change after the intervention. This is important because the strategies that were shared with the teachers are considered to be transferrable by the larger study, however, specific guidance on the topic is still necessary for improved teaching practice. This study is of the view that this peculiar need of the teachers with regards to teaching Chemistry, including Chemistry- like topics, was not known by the intervention organisers, hence no change was identifiable.

9.4. DISCUSSION OF THE FINDINGS

This study has found that the teaching practice of the three teachers did not change after participating in the intervention. This is because similar knowledge building approaches were used in one or both lessons observed pre and post intervention, thereby showing no variation in the approaches adopted to promote knowledge building in the lessons before and after the teachers had participated in the intervention. This suggests that the intervention did not change the teaching practices of these teachers, thereby failing to achieve its main objective. Hence, it resembles those professional development initiatives that failed to change the teaching practice of the teachers they were professionally developing (Kraft et al. 2018). Although there is a change in the making of links between every day and scientific ways of explaining, where instances of integration and/or differentiation were noted in the post intervention lessons only, this change is not associated with the intervention as language issues were not part of the intervention scope.

The lack of success by the blended professional development intervention to improve the teaching practice of these teachers was also evident in the observed Chemistry and Chemistry-like topics. For example, Figure 24 and Figure 30 show that Mr Jones and Mr Smith were not able to use different knowledge building approaches that promoted some relation between Chemistry content and everyday life encounters by weakening semantic density while strengthening semantic gravity. Hence only one occurrence of unpacking and repacking was observed, similar to those that were illustrated in Figure 16, Figure 18 and Figure 22. Although Mr Brown did not teach Chemistry topics in the lessons observed after the intervention, the extract below shows that he is also experiencing the same challenge as the other teachers.

> *Acids and bases I've had someone to come help me. And chemical equilibrium. But for paper one, it was fine. For me, whenever they came and did the topics, I understood. But to transmit that knowledge to the learners becomes a challenge. It became a challenge.*

Mr Brown explained that he is still experiencing some challenges with the topics he listed. The topics were addressed during the intervention; thus, it was not expected that the challenge on chemistry topics would persists. However, this extract reaffirms the challenges that were experienced by Mr Jones and Mr Smith in teaching Chemistry. Since challenge of teaching Chemistry has been identified as a need in the Content Representation sub-theme of Classroom, this implies that the intervention did not align with the needs of the teachers. This may have been an oversight from facilitators to recognise the fact that for teaching practice to change, professional development must assist the teachers in meeting their teaching and learning needs (Powell & Bodur, 2019). Therefore, as Desimone (2009), Patton et al. (2015) and Powell and Bodur (2019) stated, the needs of the teachers should inform professional development initiatives and assist the teachers in meeting these needs in order to shape teaching practice.

Although the intervention may have failed to provide teachers with strategies to improve the teaching and learning of Physical Sciences, particularly in Chemistry, it was useful in improving learner performance as indicated in the excerpts below:

> ***Mr Brown**: Compared to June, they've improved. From I think 50 something percent to 78% pass rate. I can say both [Chemistry and Physics] but more especially on the Physics side, they've improved.*
>
> ***Mr Jones**: There was an improvement with their results checking from June exam to trial examination. Although the improvement was not that satisfactory because it's still below 40. But there is an improvement. Also, there was a great improvement on paper one. Paper two, I cannot really say they improved, but they improved most in paper one, which somehow does not show the true reflection because when you combine them the marks will drop. But anyway, if there were to be separated, you would see that OK, paper one they have improved.*

In the excerpts above, the two teachers are describing the performance of their learners in the preliminary examinations, comparing it with the learners' performance in June, before the intervention. The noted improvement in the learners' pass rate is attributed to the explicit guidance provided to the teachers on how to help learners perform better in their examinations. As such, the teachers utilised these strategies to improve the pass rate of their learners. This is evident in the lesson observations as shown in the excerpts below.

***Mr Brown**: Calculate the magnitude of force F, how will we do it?*

Learners: We will use the forces that we have

Mr Brown: The first thing that you write, I want the first thing that you will write.

Learners: Fnet equals to ma (Fnet=ma)

Mr Brown: Where do you get that formula, Where?

Learners: Answer sheet…

Mr Brown: At the back of your question paper right, that formula is there. The first thing you do Learner 1, on your answer sheet, you get your formula right? It means she uses the answer sheet to copy. Now the first thing if Fnet is equal to ma, that's one mark. How many more do we need to get 1 percent as we have 1 now?

Learners: 2.

Mr Brown: 2, right?

***Mr Jones**: The boiling point of 4 organic compounds represented by the letters ABC and D are given in the table below. We have A propane…. maybe I must just draw it (draws the table on the board). Don't skip questions such as these ones, these ones are questions where you must collect marks. Actually, the first few questions it's not challenging. Challenging questions you'll get them around question 7. They're only challenging but not impossible. Define the term boiling point. Someone will go to an exam without knowing how to define boiling point. Please, don't be that kind of person. It's an abomination, and that definition it's a straightforward definition, very simple.*

***Mr Smith**: Normally this question carries around 13 marks, 12 marks, 15 marks. So, score 15 marks of 150 marks. so, if know this you will get inside the exam room with free marks. Know your definition, know how to use the equation, know how to do correct substitution. The rest is calculations.*

The excerpts above show that all the teachers paid more attention on ways in which learners can earn marks, thus passing the examination. These findings entail that these teachers found the second purpose of the intervention and its associated activities beneficial. The second purpose of the intervention was to provide teachers with strategies that would help them prepare their learners for the final examination while also improving their pass rate and performance. This, therefore, suggests that the improvement in learner performance should not be considered to be a *byproduct* of improved teaching practice as viewed by researchers (Darling-Hammond et al., 2017). This is because this view of professional development limits interventions into focusing solely on improving teaching practice without directly addressing learner performance. Since teachers participated in professional development initiatives to improve learner performance (Letloenyane & Jita, 2020), it is vitally important that learner performance be considered seperately and explicitly addressed. In addition, The teachers indicated that their confidence was boosted by the improved learner performance.

9.5. SUMMARY OF THE CHAPTER

The aim of this chapter was to present evidence showing changes, or lack thereof, in the teaching practice of the three novice Physical Sciences teachers who participated in the intervention. This chapter has provided evidence showing that the teaching practices of the three novice teachers did not change. This lack of change in teaching practice was observed largely the teaching of Chemistry and Chemistry-like topics. This study has also provided evidence showing that there was modest improvement in learner performance. This improvement has been attributed to the explicit guidance provided to the teachers in preparing the learners for their examinations. The implications of these findings were also discussed in this chapter. The next chapter presents findings and discussion on how the identified teaching and learning needs of the teachers were addressed.

CHAPTER TEN: THE INFLUENCE OF THE INTERVENTION ON THE TEACHING AND LEARNING NEEDS OF NOVICE TEACHERS

10.1. INTRODUCTION

The purpose of this study was to determine the effectiveness of the blended professional development intervention on the teaching practice of three novice Physical Sciences teachers in rural schools of Mpumalanga province. Part of addressing this purpose involved determining the teaching and learning needs of these teachers and how the identified needs were addressed by the intervention. In Chapter Seven, teaching and learning needs of the three novice Physical Sciences teachers in the rural schools of Mpumalanga province were identified. With the use of the teacher efficacy framework, discussed in chapter three, the identified teaching and learning needs of the teachers were classified into two major themes – classroom efficacy and professional efficacy. Each theme comprised of sub-themes from which the teaching and learning needs of the teachers were further classified. In this chapter, findings detailing how the identified teaching and learning needs of the teachers were addressed by the intervention. Implications of the findings are also presented in this chapter. However, firstly, a summary of the data collection and analysis process is presented.

10.2. SUMMARY OF DATA COLLECTION AND ANALYSIS PROCESS

To determine the how the identified teaching and learning needs of the teachers were addressed, the themes and sub-themes used in Chapter Seven were utilised to classify and analyse the data. The themes used in chapter seven are classroom efficacy and professional efficacy. Under classroom efficacy, the following sub-themes were used to classify the identified needs of the teachers: comprehension, content representation, instructional selection, and adaptation of content. In professional efficacy, the following sub-themes were used to classify the identified needs of the teachers: classroom management, professional identity, and professional integrity. Each identified teaching and learning need were singled out per theme and sub-theme. Thereafter, evidence showing whether the identified need was addressed by the intervention or not was sought from interviews and lesson observations conducted after the intervention. Evidence was also sought from the field notes taken during the intervention workshops as shown in Table 20. As mentioned earlier, a triangulation of data sources was used to analyse the data to ensure the reliability and validity of the findings.. The emerging findings are presented below.

10.3. FINDINGS PRESENTATION

10.3.1. Influence of the Intervention on the Teaching and Learning Needs of Novice Teachers - Classroom Efficacy

10.3.1.1. Comprehension

In Chapter Seven this study showed that teachers do not find the need to enhance learners' proficiency in non-technical terms as they believe that this should be taught in earlier grades. This finding shows that these teachers lack an understanding of the value of these terms in the learning process, as previously reported by Oyoo (2016) and Semeon and Mutekwe (2021).. However, there were instances in the lesson observations where the teachers were assisting the learners with the use of non-technical terminology, as shown in the excerpt below.

> ***Mr Brown**: OK (writes the definition on the board). Then now 8.1.2 they say calculate the resistance of each bulb. Remember they said that they are identical right, what is the meaning of identical?*
> *Learner: It means they are the same*
> ***Mr Brown**: What are you saying?*
> *Learner: It means that they are the same*
> ***Mr Brown**: That means they are the same right?*
>
> ***Mr Smith**: We said that this number (referring to hc) is a constant, is it changing or not?*
> *Learners: it's not changing.*
> ***Mr Smith**: It is not changing ne?*

Learners: yes

In the above excerpts, Mr Brown and Mr Smith were assisting their learners with the 'identical' and 'constant' terminology, respectively. However, these instances of such use of terminology were limited to one or none in all observed lessons and no change was observed in post-intervention lessons. The teachers may have been explaining these terminologies without proper appreciation of their value in the learning process, especially the fact that poor understanding of non-technical terms leads to poor conceptualisation of science content and instruction (Oyoo & Nkopodi, 2020). However, the teachers are not entirely to be blamed because the use of language in teaching and learning was not the focus of the professional development intervention. As such, the importance of these non-technical terms was not emphasised and guidance on how to address them was not provided during the intervention. Teachers may have lacked the necessary pedagogical skills to address this language issue in their lessons..

The findings of this study also showed that these teachers believe that language issues need to be addressed in early grades, so they do not pose as learning barriers in higher grades. These teachers seem to not understand that language issues vary with each topic. Each topic contains concepts that are commonly used in everyday life although bearing similar or different meaning when used in science (Oyoo, 2009). According to Scott et al. (2011), teachers must either integrate the meanings if they are similar or differentiate them if the meanings are different. As mentioned above, no instances of teachers being professionally developed on proficiency in the language of teaching and learning during the intervention workshops were noted. As such, this need has not been addressed. However, the interviews of this study seem to have brought some level of awareness of the language issue to the teachers. This is evident in Figure 23 and Figure 26, where Mr Jones started making links between every day and scientific ways of explaining in the post intervention lesson observations. These links were not made in the lessons observed before the intervention. The excerpts below depict some of the integration and differentiation instances noted in these teachers' lessons.

> ***Mr Jones****: Now let's check our equation there. Can you also see our statement there there's a lot of English in there? They are saying steam, so the steam they are referring to is the same we are used to every day* ***- integration***
>
> ***Mr Smith***: *One other area which is related to this one is astronomy. In astronomy they calculate waves or the word Galaxy in geography. Stars are in this place you know that right according to The Big Bang theory they said the earth was just like a smaller tiny object suddenly it explodes then all the planets and stars started distancing from each other but in contrast when you go to church, they say this whole universe was shapeless. And then later the word was used to say let there be light and there was light, let there be some dry land and there was some dry land. Let there be water I think it's a biblical stunt but here we talk of astronomy which is different from religious things -* ***Differentiation***

The excerpts above were taken from Mr Jones and Mr Smith's post intervention lessons. In the excerpt, Mr Jones was explaining to the learners that the term 'steam' has the same meaning in both science and everyday life. Mr Smith, on the other hand, was showing learners that science and religion have different explanations about the origin of the universe, thereby helping the learners to know and understand the acceptable explanation from a science point of view. Although these instances were observed, they were not very common in the observed lessons. Mr Jones explains the reason for the limited number of such instances in the excerpt below.

> *Yeah, with that you know it's still a bit difficult to be break down because you still need to deal with the mind of a learner. You still need to try and convince them. You still need to try and make them understand that, OK, these, like for example when you are dealing with chemistry.*

In the excerpt above, Mr Jones explains that language issues are psychological and therefore, not easy to address. Research has showed that psychological constructs are influenced by contextual factors (Wertsch, 1985). Thus, Mr Jones' view is shared by Oyoo and Nkopodi (2020) who note that language issues are influenced by the context in which they are used. The change of meaning of these terms based on context of use is one of the reasons "why even learners with high-level proficiency in a LOLT may still encounter difficulties when it comes to telling the meanings of everyday words of the same language when used in the science classroom" (Oyoo & Nkopodi, 2020, p. 475). This entails that for teachers to be able to address language issues in their classrooms, they need to know how these technical terms are used by learners in different contexts, hence supporting Mr Jones view that *'you need to deal with the mind of a learner'*. It is for this reason that Oyoo (2016) recommends that language issues be part of initial teacher education and professional development initiatives. Oyoo and Nkopodi (2020) add that it should be a policy for teachers to address language issues in their lessons for learners. These changes will improve teachers' competency in addressing language issues, thereby improving learners' proficiency and comprehension of science content.

10.3.1.2. Content Representation

This study found that teachers face challenges in teaching the Chemistry content, especially on coming up with analogies and examples from everyday life that can be used to aid understanding of the Chemistry content. This challenge appears to have not been addressed for Mr Brown, as evident in the except below where he notes what he learned during the intervention workshops.

> *OK for specific topics, I won't say I've learned anything. But I've learned something about something else that when making example, make use of things that the learners know. Don't make examples that you see online. In electricity you must not talk about hydropower station or nuclei stations, you must speak of Eskom which they know. So, when making examples, relating science with its application, you must make examples using something they can see every day and know. That works best for the learners. That's what I 've learned, whenever they were making examples there. Those examples were of things you see every day.*

The excerpt above shows that Mr Brown has learned about the use of examples in lessons. However, Mr Brown used a Physics topic, instead of a Chemistry one, to make an example of what he has learned. The use of examples and analogies in this subject has been an issue in Chemistry as discussed in Chapter Seven. Thus, his reference to Physics topics indicates that he has not gained knowledge on how he can make Chemistry content accessible to his learners using examples and analogies from everyday life. Even though Mr Brown did not teach Chemistry topics in his post-intervention lessons to further substantiate this finding, the excerpt below does show that he is still had difficulties in presenting Chemistry content.

> *Acids and bases I've had someone to come help me. And chemical equilibrium. But for paper one, it was fine. For me, whenever they came and did the topics, I understood. But to transmit that knowledge to the learners becomes a challenge. It became a challenge.*

The excerpt above shows that Mr Brown continued to experience challenges when teaching Chemistry topics, as evident by the seeking of assistance from a fellow teacher. These challenges include presenting the content, which requires unpacking and repacking the concepts for the learners. The topics he called someone to assist with were dealt with during the intervention workshops. The Acids and Bases topic was addressed in Workshop 5 while Workshop 6 focused on Chemical Equilibrium along with the topic of Rates of Reaction, as shown in Table 6. This shows that Mr Brown continued to experience challenges around the teaching of Chemistry. This may also be the case for Mr Smith since he continued to teach Physics topics, without a single lesson on Chemistry, during his post-intervention lessons indicating that he had not yet gained confidence in teaching the topics in this component of Physical Sciences. This was also shown in Figure 30, where he was teaching a Chemistry-like topic, Photoelectric effect, and did not unpack the content using knowledge building approaches to relate the content to everyday life encounters on simple phenomena, complex phenomena, and analogies.

Mr Jones also experienced challenges while teaching Chemistry topics. This is because only one instance of unpacking is observed in this first post intervention lesson (Figure 24), where he was teaching the topic of Chemical Equilibrium. As such, this lesson resembles his pre-intervention lessons (Figure 21 and Figure 22) that had only one instance of unpacking and repacking. Although numerous instances of unpacking and repacking were observed in his second post intervention lesson (Figure 25), the approaches commonly used to unpack the content (diagrams) were on intricate parts of the content and could not be left out when teaching the topic. Therefore, even though he used other knowledge building approaches, besides diagrams, in his second post intervention lesson (Figure 25), their instances were limited. The limited number of such instances in Organic Chemistry lesson cannot be used as evidence that his teaching practice had changed after participating in the intervention, particularly because he was absent when this topic was addressed in Workshop 8. Since he was absent when the Organic Chemistry topic was addressed in the intervention, the observed instances of unpacking, besides using diagrams, may have been accumulated from his experience in teaching Physical Sciences. As such, this study maintains that Mr Jones continued to experience challenges in teaching Chemistry topics, other than Organic Chemistry, just like Mr Brown and Mr Smith.

This study also found that these teachers also experienced challenges when teaching some Physics topics. This is evident in the excerpt below where the Mr Smith was listing topics learners often find difficult. Although he is referring to these topics as challenging for learners, the intervention was not meant for the learners but for teachers. Since Letloenyane and Jita (2020) reported that teachers would participate in any profesisonal devlopment inititative to improve the performance of their learners, then the topics that Mr Smith listed are those he would like to be professionally developed on if the intervention was to proceed so to improve the performance of the learners on those topics.

> *But if this project was to continue, they are topics that learners normally don't try. A section on electricity. Learners, they just brush away. Work energy and power, they always run away. In paper two, equilibrium calculation, Kc calculations, they normally run away. So, if the project continues, work energy and power should be there. Electricity should be addressed fully, not just introduced. No, no, no. And equilibrium constant calculation. With pH, they don't struggle with that one.*

In the excerpt above, Mr Smith listed (1) Work energy and power (2) equilibrium calculations or equilibrium constant calculations (3), Kc calculations (4) Electricity as topics he would like to be professionally developed on. From the list, topics 2 and 3 are sub-topics under Chemical Equilibrium and were therefore addressed in workshop 6. However, since Mr Smith listed them, it entailed that he still needed more opportunities for development around this topic. Mr Brown had to also request another teacher to teach the Chemical Equilibrium topic on his behalf after the intervention even though he attended the workshop. This finding emphasises that the time given to this topic during the intervention was not sufficient to develop teachers' competency in teaching it as indicated in Chapter Eight. Furthermore, it demonstrates that the challenges of these teachers in teaching Chemistry topics persisted, particularly in the topic of Chemical Equilibrium as evident in the excerpt above as well as Mr Jones first post intervention lesson.

Beside the sub-topics of Chemical Equilibrium, topics 1 and 4 are from the Physics component, and were not addressed during the intervention. From the listed topics, the topic of Electricity seem to be challenging as Mr Brown also mentioned it in the excerpt below.

> *There's a topic I am having a challenge with and if it was covered, I don't know how many percent I would have gotten. I never knew that these learners had a challenge until the trial exam. Its Electricity in physics. So maybe if it was covered and I had picked up that they have a challenge there…*

Based on the poor performance of his learners, Mr Brown, in the excerpt above, suggests that this topic should have been addressed so he could learn effective strategies on how to present it to his learners. The demand of these topics is based on the positive impresssion the teachers had about the strategies they learned on how to improve learner performance in the Electrodynamics topic as shown in the excerpt below.

> ***Mr Brown:*** *There was a strategy that the facilitator was using on paper one on Electrodynamics. I have copied that one the way it is. I came with it to my learners, and they understood within few minutes. I know that they are good in that topic. I think maybe it's because of the way she taught the lesson. Then I also came and taught the same way and learners were able to grasp it quick.*

> ***Mr Jones:*** *Umm, actually after attending those classes with you, the one physical we attended at School D, some strategies we took and we made use of them. They improved mostly on the topic Electrodynamics. Most of them got total.*

In the excerpts above, Mr Brown and Mr Jones are express how efffective the strategies they learned on the topic of Electrodynamics were as they improved the performance of their learners. There is nothing that Mr Smith had to say about this topic as he missed this workshop. Therefore, while the intervention did help the teachers with their needs regarding the teaching of Chemistry, it was useful in addressing dshare strategies that could be used to improve perfomance in some of the Physics topics, e.g. Electrodynamics.

This study also found that the teachers were aware of the language barrier posed by the language of teaching and learning, English. However, they lack the knowledge of the methods they could use to improve proficiency of this language in their lessons. These strategies were not shared with the teachers during the intervention workshops. As such, teachers were not promoting English proficiency in their lessons even after participating in the intervention. Learners continued to use their home language, Xitsonga, to engage with their teachers while the teachers remained oblivious to this. Therefore, this need remains unaddressed, mainly because the intervention was not focusing on this aspect. Thus, strategies on how teachers can promote proficiency in the LOLT during science lessons were not shared with the teachers. This entails that learners continue to find it difficult to complete assessments that require English responses if their proficiency in LOLT is not enhanced (Mavuru & Ramnarain, 2020).

10.3.1.3. Instructional Selection

This study found that the teachers' choice of instruction is influenced by the availability of teaching and learning material. Teachers expressed how learners are expected to memorise the content, particularly in Chemistry, without any visuals to aid understanding. The teachers, except for Mr Smith, were given materials to use to conduct experiments that could be used to aid understanding. However, this study found that teachers lack knowledge of conducting experiments that can aid understanding besides the prescribed ones for assessment. This study found that although some teachers did have resources that they could use to aid learning, besides doing the prescribed assessments, they could not do anything else with the materials. Additionally, teachers did not seem to know how to use the given material. Although the intervention attempted to address the availability of teaching materials need, this it was not entirely addressed. Instead, it exposed another need, which is knowledge to effectively use the material to aid learning without relying on prescribed practical assessments.

Teachers lack the required knowledge of how to effectively use available technological resources to enhance learning. For example, Mr Jones and Mr Brown did not utilise the projectors available in their schools for teaching purposes. They do not use simulations which are readily available to enable understanding of matter at microscopic level. Mr Brown was the only teacher who showed awareness of this technological resource. However, assistance in addressing the compatibility of his laptop with the Java software was not provided. During the intervention, the affordances of using available technology to effectively enhance learning were not shared and explored with the teachers. As such, this need remains unaddressed too.

This study also found out that teachers were aware of the importance of including practical experiments in their lessons. However, their consideration of this teaching and learning material is limited to the macroscopic level - to keep learners interested in the subject. This limited view revealed that teachers need assistance on how to effectively use macroscopic observations to enable understanding of matter beyond the macroscopic level.

During the workshop on the topic of Rates and Extent of Reaction, the use of everyday life materials was encouraged. The facilitator mentioned materials such as tea bags with hot and cold water, sugar and etc, that could be used, instead of scientific materials, to illustrate the concept of rate of reaction. From this knowledge, teachers were shown how to effectively relate what will be observed during the experiment with what is happening at microscopic level. Such a demonstration left a lasting impression on Mr Smith as shown in the excerpt below.

> *The one I would adopt was a section on chemistry. Was it the rate of reaction, something like that. They mentioned that if we don't have those prescribed apparatus, you can come up with your own practical resources that they are familiar with so they can understand the concept. I think she touched a lot of examples in there, yeah.*

The excerpt above shows what Mr Smith learned more about experiments during the intervention. Such a strategy is beneficial for rural schools because they lack teaching and learning resources, especially in science (Mukeredzi, 2013). Clearly, teachers need more examples on the utility of these kinds of illustrations.

Chapter seven revealed that teachers needed assistance in the methods they could use to effectively engage their learners in and out of class. This need was necessitated by the emergence of the COVID-19 pandemic, which disturbed the teaching plan and traditional mode of teaching, thereby limiting the teaching time. These strategies were not explored with the teachers. This is because this need was not within the scope of what the organisers of the intervention intended to accomplish with the teachers.

10.3.1.4. Adaptation of Content

This study found that teachers lack knowledge of adapting instruction to the learning needs of the learners. As a result, they find themselves spending more than the scheduled time on each topic. Adapting instruction requires teachers to critically plan and reflect on their lessons. However, this study found out that teachers seem to believe that with time they do not need to critically plan and reflect on the lessons. Unfortunately, teachers were engaging passively during the intervention workshops as they were not given activities to complete in order to obtain feedback from facilitators as part of enhancing their planning and reflection skills. Reflection supports effective engagement (Prestridge & Tondeur, 2015) and can be fostered with feedback (Philipsen et al., 2019). Templates that may be used to critically reflect on lessons were shared with the teachers. However, none of the teachers submitted the templates with their reflections. These two aspects did not help the teachers in adapting their lessons to the needs of their learners. However, Mr Smith noted something about teaching this subject, as show in excerpt below.

> *For what I've realised before they introduce a lesson, they spotted out misconceptions that you might encounter when you dwell in that chapter. So, they tend to show exactly the usage of a concept in the normal language and its meaning in science. So, it's different from what you people are talking outside. So, they addressed chapter with some… they put their specifications that in this chapter are going to express this and this and this. So, you get there being inclined, and you know exactly which maybe it's a term must be explained fully to avoid the misconceptions.*

In the excerpt above, Mr Smith is describing what learned about how lessons should be structured. He explained misconceptions that learners may have on a particulate topic.. Identification of misconceptions on each topic is essential in the transformation of subject content knowledge (SCK) to enable conceptual understanding. Thus, it is important in adapting content to the needs of the learners. He outlined that that concepts have scientific meaning in addition to everyday use in different contexts.. However, this was not the case as definitions of these terms were outlined only, as per the examination guideline, before the content of the topic could be addressed in each workshop. Therefore, through the workshops' presentations, strategies of adapting content to the needs of the learners were shared with the teachers.

10.3.2. Influence of the Intervention on the Teaching and Learning Needs of Novice Teachers - Professional Efficacy

10.3.2.1. Classroom Management

The findings of this study demonstrate that there out there is shortage of textbooks for teachers. In some instances, they select poor quality textbooks. As such, they need assistance in selecting good quality textbooks for their learners. This need was not addressed as the focus of the professional development was on improving teachers' effectiveness in terms of teaching while assisting them when preparing their learners for examinations. Therefore, no time was spared in professionally developing the teachers on selecting quality textbooks for their learners. However, through the materials shared with the teachers, the need for textbooks was partly addressed, as Mr Smith indicated below.

> *Yeah, the material is very much useful, very much useful. I don't know where you guys were some years back because we don't find these things. Your source is the textbook, we don't have any other means. It's not teachable. Yeah, but having different sources is helpful. Learners can even create their own group. Some you post when you are at home, when we get in here, you just duplicate the hard copies then you do. It's manageable. Yeah, they are very good.*

Although teachers were not provided with textbooks or knowledge on how to select them, they were given pamphlets with questions that they could use for class activities as well as videos that they could use to aid understanding. Mr Smith, in the excerpt above, explains that he found these resources useful as he could easily share them with his learners. Mr Jones also shared the same sentiments as Mr Smith, as shown below.

You know what I did, I tried to make copies of everything that we received. Most of the things that I needed to give them, learners. And then I gave them. They use them as their notes. The questions that were there, we wrote them as activities. I think it really helped because when you check their performance, you can tell that these learners were sure of what they were writing. You know, with electrodynamics, for example, I used mostly the material. It's not really easy to understand, but it's easy to answer. You can answer and get a total without understanding, but this time around we were understanding. I remember the pamphlet that we were given, I made copies for each, and every learner and it was easy for me to teach, teaching them knowing what I'm teaching and having strategies to teach them. Like you even feel more comfortable to explain whatever that you are explaining. Unlike having to explain something that you don't even know, we are just explaining because they said this is done this way. Yeah, so those pamphlets were very useful.

In the excerpt above, Mr Jones is explained that he printed the presentation slides for his learners to use as notes as well as the pamphlets to use as activities. Mr Jones explained that these materials helped in improving his confidence in teaching the topics. Mr Brown also shared the same sentiments as Mr Jones in the excerpt below.

Yes, it [the way he is teaching] has changed. I don't know how it has changed but I can see that it has changed. But how, I won't tell you. Yes, [I feel confident] and now I am more active than before. I own that class now and the kids are scared of me now.

Mr Brown is explained that his teaching practice changed, even though he could not really pinpoint exactly what changed about the way he teaches. He noted that he is now more confident and active in his class. He uses 'scared of me' to show that his learners respect him more now because of the improved confidence in his teaching. Similar to Mr Jones, the materials that were shared with the teachers, along with the workshops, contributed to the teachers' improved confidence in their teaching practice. Therefore, the materials developed by the intervention were useful in addressing the challenge of the shortage of textbooks in these schools.

Teachers expressed the need for facilitators to visit their classes and demonstrate the approaches they were sharing with them. This need was partly addressed during the last two workshops on Mechanics and Organic Chemistry that were conducted at Mr Brown's school. During the workshop, the facilitator took on the teacher's role and taught Mr Brown's learners while all the teachers observed. The excerpt below underscores Mr Smith's view regarding this approach.

> *Uh, I think in the near future it would be best if like they did last intervention workshop at School C where learners were amongst us. Yeah, I think that strategy can do miracles. Yeah, go to combine a whole lot of schools, it will require some financial muscles, yeah, but I think that could help. Yeah, because seeing different faces, presenting different chapters, it helps them. What happened after you left, we had a group of teachers rushing to School D to assist. Teachers from different schools, each teacher was given a topic to address. We had this on Saturday and Sunday. So, it helps if they see different people. Yeah, you see the approach will be different as well. Like I said, let us invite teachers but they should interchange at times and invite learners from those clustered circuit to be in one centre and be addressed. Things like that, yeah.*

Here Mr Smith elaborated on the effectiveness of this approach whereby facilitators teach learners during the last two workshops at School A. He explains how this approach was then adopted to assist School D after the intervention had ended. Mr Smith further indicated that this approach was effective and should be adopted going forward as it requires each teacher to teach a topic they are confident in. This approach ensured that learners receive quality education.

Teachers have expressed the need for additional classes on weekends and holidays to be introduced and facilitated by other people so that teachers can have time to rest. This included the need for an additional teacher in School B to assist Mr Jones with his workload. This need was beyond the scope of the professional development intervention. Hence, nothing could be done to address this need. However, recommendations to the relevant authorities or stakeholders are in order and could assist in addressing this need.

10.3.2.2. Identity Development

This study found out the main goal of the teachers that participated in the intervention was to obtain a100% pass rate in their subjects. This need appears to have been addressed as the teachers found the acquired strategies to be beneficial in their teaching, as Mr Brown expresses in the excerpt below.

> *During that workshop, actually we were taught how to answer question papers. With me, I am new in this industry so those things, I never knew them. Even with my learners I do not mention them. When I am teaching, I am not using the marking guideline. But on that workshop when they were teaching, they were using the marking guideline to motivate the learners that if you do this, there's a mark for this. So, a learner knows that for this question I must start with this thing because there's a mark for that. Right now, it's not easy for them to forget things because they know that there's something, maybe question two there's a mark for…if ever there's a definition, the following question will use the definition formula. Because you know definitions are derived from formula. I learnt that here (on the workshop). I never knew that if the first question is a definition, the next question will require you to use the formula. And if I check the question papers, most of them it's like that. So, I can say, it really benefitted us a lot.*

In the excerpt above, Mr Brown is explaining how the strategies on improving learner performance have been eye-opening for him, especially since he is a novice teacher in the profession. According to Mr Brown, the shared teaching strategies motivate the learners and improve their performance in the subject. Mr Brown and Mr Jones have revealed that they implemented the strategies Mr Brown described above and they have improved the performance of their learners. However, this was not the case for Mr Smith as only four out of twenty-four learners performed well in the preliminary examination. Thus, the observed confidence in the teaching of Mr Brown and Mr Jones is a direct result of the shared strategies, coupled with the given teaching and learning material. The increase in confidence is an indication that these teachers established their professional identities, identifying themselves as Grade 12 Physical Sciences teachers.

Furthermore, the intervention afforded Mr Brown an opportunity to network as he is now able to call on other teachers to assist him whenever he encounters some teaching and learning challenges. All the teachers under investigation adopted this intervention strategy to address teaching challenges experienced in School D. This approach opened doors for improved engagements amongst the teachers in the circuit, while also diminishing the isolation posed by the long distance between neighbouring schools.

Mr Jones gained valuable information from the highly experienced facilitator. Mr Jones had expressed his concern over challenges he sometimes encounters when teaching of Electrochemistry, Electrodynamics and Rates and Extent of Reactions. By engaging with the experienced facilitator, Mr Jones explains that some of the challenges he had were addressed, as shown below.

> *OK, I don't know much about the B.Ed. group. With us B.Sc., my B.Sc. is not much more of practicals where you have to do practicals and use chemicals. I do B.Sc. in pure maths. So having to intervene like you did, like attend the intervention, I think it was more beneficial to me because I was exposed to most of the things which I was not even aware of. It did help me because I'm just branching from something like jumping not knowing what is happening in between. So, the workshop was able to break, not all but most of the important stuff which I was not even sure of, and then at least they tried to make me to be knowledgeable. So yeah, it was good experience.*

Therefore, the intervention did partly address the need of Mr Jones to be workshopped by a highly experienced facilitator who is knowledgeable about challenges on all the topics in the subject and how to address them. This helped Mr Jones on his path to developing his own professional identity as a Physical Sciences teacher, thus improving his professional efficacy.

For Mr Smith, shared strategies on improving learners' performance in the examination did not seem to work. This may have been attributed to his absence during the first workshop, which benefitted other teachers quite significantly. Furthermore, he attended the last four workshops only, thus missed learning opportunities to improve learners' performance in the workshops he did not attend. However, Mr Smith attributes poor performance to learners' lack of commitment to their studies, as shown and discussed in Chapter Seven. In the excerpt below, he explains how he will continue to use the strategies he learned from the intervention.

> *We employed all strategies, like after they've written the trial [preliminary examination], during this time, we don't normally teach them in one class, they are grouped according to their potential. So, we are trying to pick exactly where the problem lies because when they are in one class, some are hiding. So, we tried to employ all the strategies, the one we learned from the workshops. Techniques, giving material all sort of stuff. So, we hope for the best.*

Mr Smith indicated that his learners will be separated into groups, based on their performance, and will employ all the strategies learned during the intervention to prepare learners for their final examination. The outlined approach and excerpt above reveal that Mr Smith's conceptions about Mathematics and Science learners are supported by his school. Since peoples' attitude influences their behaviour (Ekperi et al., 2019; Ulug et al., 2011), Mr Smith might not provide the required support to these learners with 'less potential', thereby affecting their performance in the subject. Mr Smith conceptions must be changed as research shows that teachers may have the potential of instigating poor performance (Ekperi et al., 2019; Ulug et al., 2011).

Mr Smith is not qualified to teach Physical Sciences, but he is qualified to teach Natural Science and Mathematics, as shown in Table 10. He has been teaching Mathematics for 16 years with only 2 years of teaching Physical Sciences. Thus, Mr Smith is an off-field novice teacher of Physical Sciences. It is, therefore, the view of this study that the poor performance of his learners and lack of potential Mathematics and Science could be a reflection of his lack of qualification in teaching Physical Sciences. According to Ingersoll (2001), teaching off-field renders highly qualified teachers unqualified, hence learners that are taught by unqualified teachers are most likely to perform poorly as compared to learners that are taught by qualified teachers. This is because these teachers lack SCK which, according to Magnusson et al. (1999) and Shulman (1986), is fundamental in developing PCK for the subject. Thus, Ingersoll (1999), argues that off-field teachers are ineffective in promoting intellectual engagement and enthusiasm in learners. Mr Smith's challenge in Physics may have been addressed during the intervention workshops, however, Table 22 shows that he mainly attended workshops on Chemistry. Furthermore, the lack of individual support of the professional development intervention may have attributed to his continued challenges in teaching Physical Sciences. Therefore, the intervention did not assist Mr Smith in establishing his professional identity as a Physical Sciences teacher.

10.3.2.3. Professional Integrity

All the teachers in this study had strong preference of Physics over Chemistry. Even so, they were teaching both components of Physical Sciences to their learners. Mr Brown and Mr Smith were observed teaching Chemistry in their lessons while Mr Smith taught Physics only on all his observed lessons. This should not be taken to mean that Mr Smith did not teach Chemistry to his learners. Rather, he is still developing himself in this area.. However, he is not yet comfortable to be observed teaching it. Therefore, more workshops that can develop his SCK and PCK in Chemistry should be conducted. These workshops will also be beneficial to Mr Jones as he is also teaching out of field. They will also be beneficial to Mr Brown as he is having challenges with teaching Chemistry.

10.4. DISCUSSION OF THE FINDINGS

This chapter has revealed that issues of language in teaching and learning were not addressed by the intervention as part of its content focus as per the Effective blended professional development framework. This includes professional development in the use of non-technical terms in the learning process, consideration of changes in the meaning of technical terms due to context including the development of general proficiency in the language of teaching and learning. Although not addressed in the intervention, the interviews held with the teachers brought to the fore some level of awareness of the language issues that can potentially hinder learning, particularly the overlap in the use of technical concepts in more than one context with similar or different meanings. These instances, although few, were observed in all the teachers' lessons (shown in Figure 17, Figure 20, Figure 26, Figure 29 and Figure 32), except Mr Jones pre-intervention lessons, where integration and/or differentiation was utilised.

However, these language issues must be thoroughly addressed during teachers' professional development, as per Oyoo (2016) suggestion, giving the fact that teachers require knowledge and skills to address these language issues in their teaching. This implies that there is a need for intensive research that can come up with strategies that can be used to effectively address language issues in teacher professional development initiatives and initial teacher training programmes. Once these strategies have been developed, this study maintains that they should form part of the content focus of professional development alongside SCK and PCK as shown in Figure 4. This will enable the teachers to develop their competency in each of the language issues outlined in Chapter Seven per topic in the subject, thereby enhancing their comprehension of the SCK and PCK – classroom efficacy. Professionally developing the teachers in these language issues will ensure that the initiatives are responsive towards the needs and interests of learners as Bayar (2014) posited, since these languages issues hinder conceptualisation of SCK (Oyoo, 2016).

Besides lack of professional development in language issues, this study discovered that the teachers were not adequately developed in teaching Chemistry topics – content representation. For example, this study has provided evidence to show that Mr Brown and Mr Smith continued to experience difficulties in teaching Chemical Equilibrium, a Chemistry topic, after having participated in the intervention. This chapter has revealed that this persisting difficulty in teaching Chemistry may be the result of lack of sufficient time to professionally develop teachers on the topics. This study noted that the Chemical Equilibrium topic was taught alongside the Rates of Reaction topic during workshop 6, within two hours. Two hours were adequate for only one topic, e.g. Rate of Reactions. A further two hours should have been dedicated to the other topics, e.g. Chemical Equilibrium. Therefore, adequate time must be committed to each topic during professional development, with a minimum of twenty hours contact time for the overall initiative, as suggested by Desimone (2009), on shaping teaching practice.

In addition to the period of contact time being longer, this study maintains that the content of the professional development - topics per subject, must be those that the teachers have identified as challenging, thereby requiring professional development. For this intervention, the topics would include Work, Energy and Power and Electricity as outlined by Mr Smith and Brown as well as those topics that many teachers noted as being difficult in Figure 11. This would ensure that the professional development intervention is relevant and useful to the teachers, following Bayar's (2014) and Kaino et al.'s (2015) suggestions on meeting the coherence requirement of the Effective blended professional development framework. Furthermore, it would ensure that these teachers are competent in all components of Physical Sciences, enabling them to better prepare their learners for studies in higher education in either Chemistry or Physics.

Although the intervention may not have given the teachers sufficient time to engage with the content and develop themselves, the challenges outlined in Chapter Eight significantly influenced the teachers' access to knowledge. For example, not only was Mr Brown facing challenges in teaching Chemical Equilibrium, but also had challenges in teaching the topic of Acids and Bases. He actually requested the assistance of another teacher after having participated in the intervention. Table 22 in Chapter Eight shows that Mr Brown did not attend workshop 5 which was focusing on the Acids and Bases topic. Unlike the Chemical Equilibrium topic, Acids and Bases were taught for a full two hours, indicating that it was given the same amount of time as the other topics. Hence, Mr Smith did not list it as one of those topics he needed professional development on after attending it.

The implication of the abovementioned finding is that Mr Brown may have also benefited from that workshop on this topic had he attended. Mr Brown missed this workshop and the other online workshops (workshop 4) due to limited access to data, a factor he revealed and strongly emphasised as impeding his attendance and engagement in online workshops. Similar findings were reported by Mukuna and Aloka (2020) and (Campbell, 2019). Therefore, this study maintains that the digital tools listed in Figure 4 and suggested by Mukuna and Aloka (2020) must be made available to enable the teachers' access to online workshops.

Furthermore, asynchronous professional development and/or face-to-face workshops must be adopted, coupled with authentic tasks and reflection opportunities, to counteract the effect of poor network coverage that has hindered Mr Jones from attending online workshops. In adopting the asynchronous mode of professional development, teachers must be well trained on how they are expected to engage in this mode, so as to prevent them from developing a negative attitude that might impede their engagement, as reported Belland et al. (2015).. In adopting face-to-face workshops, this study maintains that teachers must be provided with financial support, to take care of travelling costs to and from the intervention venue. This will motivate the teachers, thus encouraging them to attend not for themselves but for their learners and their school as well.

Other than the abovementioned issues, this study revealed that the difficulties faced in teaching Chemistry continue to persist because not much information was shared with the teachers on the possible analogies and examples that could be useful in each topic, except in the Rates of Reaction topic. Strategies on how to teach the Rate of Reactions topic included information on readily available materials, such as tea, sugar and etc. Teaching resources, micro-kits, were also given to the teachers to use in their teaching of Physical Sciences, as a way to address the lack of teaching and learning resources. However, no information was shared regarding the possible experiments that the teachers could perform with the given micro-kits to enhance learners understanding of the SCK. This study realises this lack of information as a loophole in the intervention. Therefore, it maintains that teachers need to be provided with information on relevant and readily available teaching and learning resources, including analogies and examples that could be used to aid learning per topic in the subject should be shared with the teachers. This should also comprise of information on possible simulations per topic, how to effectively utilise them in teaching as this study has also revealed that Mr Smith and Jones may be unaware of these learning resources, and how to access them as Mr Brown had difficulties in accessing them. This would improve the teachers' classroom efficacy in terms of instructional selection as teaching and learning resources influence the choice of instruction (Ramohapi et al., 2015).

Since the teachers showed limited knowledge of conducting experiments, this study maintains that teachers need to be trained to acquire knowledge and skills of conducting experiments, other than the ones prescribed on the curriculum, based on the availability of materials to promote learning. This should include methods that teachers could use to relate observations at macroscopic level to microscopic and symbolic level. As previously mentioned, this will ensure that teachers are competent in developing learners' holistic understanding of the SCK, especially in Chemistry, thus ensuring that teachers understanding of experiments is not limited to the elicitation of interest and motivation. It is therefore the view of this study that the intervention did not make any significant improvements in the classroom efficacy of these teachers in terms of content representation and instructional selection. This is especially the case with Chemistry, and a bit about Physics with the few topics listed as challenging in Figure 11 yet not addressed by the intervention.

Although the intervention fell short in helping teachers to represent content, especially in Chemistry, evidence provided above shows that it did help the teachers with identifying possible misconceptions that learners may have per topic. In addition, difficult concepts were implicitly outlined and strategies to address them were shared with the teachers. These were to assist the teachers with adapting the content to the needs and level of the learners. However, the teachers were not given authentic tasks and opportunities to critically reflect on their attempts to implement the learned strategies were not utilised, as per the Effective blended professional development framework. As such, teachers did not receive any assistance in successfully implementing the learned strategies to help them adapt content to the needs and level of the learners, leading into the intervention resembling those conducted by DBE as Bantwini and King-McKenzie (2011) reported. The resulting failure by the teachers to implement the shared strategies is commonly considered as resistance to change (Bantwini & King-McKenzie, 2011). To assist the teachers with the implementation of the shared teaching and learning strategies, coaching/mentoring should be introduced and would be of great help to the teachers, especially the novices and off-field teachers. The mentors/coaches must provide the teachers with assistant in their working environment since Mushayikwa (2009) has established that the professional development must take place in a context resembling the teachers' working environment for it to be fruitful and ensure sustainability. Since the mentors/coaches would observe the teachers' lessons and provide them with constructive feedback, it would address the expressed need of these teachers to have facilitators visiting their classes. The mentors/coaches must also participate in a comprehensive training as Kennedy (2005) and Mukeredzi (2013) suggested to ensure that they are competent in providing the required individual support to the teachers.

Although the intervention did not help the teachers much with content representation, it did partially help the teachers address challenges around lack of textbooks. This is because the teachers were provided with pamphlets that can be used for teaching and learning and were found to be very helpful by the teachers. However, they were not professionally developed on how to develop such materials such that it could be easy to use and develop them for conceptual understanding. It is important for teachers to be professionally developed on how to create these teaching and learning materials by themselves. With such skills, the teachers would be able to use this material to engage learners beyond school hours and the learners will be able to work on their own as the material is learner friendly. However, coaches/mentors will be required to assist the teachers as they develop these materials for their learners. Once carefully developed, these teaching and learning materials will save the teachers quite some time, easing the experienced pressure and lack of personal time observed in this study and reported by Hunt-Barron et al. (2015) and Tsiotakis and Jimoyiannis (2016).

The teaching and learning materials are useful in aiding the teachers' goal to achieve 100% learner pass rate. This is because they are developed based on the marking scheme and structure used in the final Grade 12 Physical Sciences examination papers. Therefore, if they are carefully developed, they can equip the learners with the required skills to answer question papers, understand the structure of the question paper and how to earn marks in each type of question. Although the teacher would still be expected to emphasise the abovementioned strategies, the learners will be able to revise what they have learned while preparing themselves for examinations using the developed teaching and learning material. Not only is this material useful to the learners, but it is also useful to the teachers as it has contributed to the newfound confidence of Mr Jones and Mr Brown in teaching the SCK and preparing their learners for the final examinations. In other words, professionally developing the teachers on creating the teaching and learning material and use it to obtain 100% learner pass rate will significantly contributes to their professional identity. Therefore, this study maintains that the intervention should include the development of teaching and learning materials to fully develop the professional identities of novice and off-field teachers.

It is important to note that the development of teaching and learning material is one of the many methods to develop teachers' professional identity. For example, Mr Jones also gained his confidence from the newly acquired knowledge on some challenges he has within certain topics, similar to Mr Brown. Some of these challenges are the result of being unfamiliar with the way things are done in the teaching profession since he has and still pursuing Bachelor of Science degrees. In other words, teachers' background, and competency in teaching the subject contributes to ones' professional identity. Hence, the intervention was accommodative to these teachers by sharing strategies that would elevate their learners' performance in the subject, e.g. the teaching and learning material and methods of adapting content to learners' level and needs. However, the abovementioned strategies on enhancing teachers' competence in content representation, instructional selection and comprehension should be included in the intervention to professionally develop the teachers' classroom efficacy holistically.

Attitude towards the subject, profession and learners also matters in developing one's professional identity and integrity. This is evident in Mr Smith's case where he categorises learners according to learners' abilities based on his attitude towards science that it is reserved for the mathematically inclined learners only. Such attitude is likely to perpetuate poor performance as Mr Smith is likely to pay more attention to the 'Mathematically inclined' learners and less effort to the other learners. This is because research shows that people perform better on subjects that are of interests to them and poorly on those that are unfavourable (Ekperi et al., 2019; Ramohapi et al., 2015; Ulug et al., 2011). Therefore, the intervention needs to do more in helping the teachers in being responsive to the needs and level of learners, thereby diminishing such prejudice attitudes towards the learners. This study has indicated that Mr Smith's attitude may be the result of his unique background as an off-field teacher with 16 years teaching experience in teaching Mathematics and less than two years in Physical Sciences, causing him to experience 'transfer shock'. Although Mr Smith was not observed teaching Chemistry, it is the view of this study that he is making efforts to develop his competence in this component as he attended most workshops that were focusing on this component, as shown in Table 22.

This study is of the view that Mr Smith's attitude will *ease* provided he is given the necessary guidance on how to teach the subject. This study uses the term 'ease' to emphasise that the attitude will not completely diminish due to improved learner performance. This is because this attitude has been developed with the accumulated 16 years of teaching experience. Also, his attendance of Chemistry workshops indicates that he considers his lack of competence on this component to be severe compared to Physics. However, Mr Smith has been out of touch with Physics for the entire 16 years and numerous changes have been implemented in the curriculum within this period. Furthermore, he did not specialise in this subject on his teaching qualification. As such, he needs professional development on all components of Physical Sciences. Therefore, the intervention should consider introducing coaching/mentoring to provide the teachers with assistance tailored to their individual needs. The coaching/mentoring models must be introduced in addition to authentic activities that will provide them with the necessary knowledge and skills to teach Physical

Sciences. Furthermore, adequate time should be committed to their professional development with a focus on all the topics they have identified as challenging in Figure 4.

10.5. SUMMARY OF THE CHAPTER

The aim of this chapter was to present findings obtained in determining whether the teaching and learning needs of the novice Physical Sciences teachers identified in Chapter Seven were addressed by the intervention. If addressed, this chapter has elaborated on how the identified needs were addressed. Triangulation of data collection methods – lesson observations and interviews, were used to determine the findings presented above. In addition, triangulation of data sources was used to obtain the findings presented above where evidence was drawn from field notes written during the intervention workshops as well as lesson observations and interviews collected after the intervention.

In summary, this chapter has showed that the teachers were not adequately developed in representing content for Chemistry topics. They were also not adequately developed in instructional selection which involves the use of teaching resources, such as micro-kits. However, the pamphlets, given as a teaching and learning material along with the shared strategies of preparing learners for examinations contributed significantly to Mr Brown and Jones newfound confidence. Using the acquired knowledge, Mr Brown and Jones reported an improvement in the performance of their learners, which is in contrast to Mr Smith's learner performance. This study has noted that the unique background of Mr Smith demands comprehensive individual support through the provision of coaching/mentoring model. The next chapter will present conclusion and recommendations drawn from the overall findings of this study.

CHAPTER ELEVEN: CONCLUSION AND RECOMMENDATIONS

11.1. INTRODUCTION

The main goal of this study was to examine the effectiveness of blended professional development intervention administered to Grade 12 Physical Sciences teachers in a rural circuit of Mpumalanga province. The purpose of the intervention was to assist teachers in teaching the content of the topics covered during the intervention workshops. The intervention also intended to provide teachers with strategies that would help them prepare their learners for the final examination while also improving their pass rate and performance. Therefore, the training model from the transmission category and community of practice from the translational category were employed. When these two models were combined, they produced a transformative model which was used to promote the professional development of the teachers. The blended nature of the professional development intervention comes from some workshops being conducted online using Microsoft Teams and others being face-to-face. In addition, a WhatsApp group was created with the aim of promoting collaboration amongst teachers as well as teachers and facilitators. The intervention took a total of 16 hours, where teachers were workshopped on the following topics in Grade 12 Physical Sciences: Mechanics; Electrodynamics; Electrochemistry; Acids and bases; Rates of Reactions; Chemical Equilibrium and Organic Chemistry. The selection of these topics was informed by their weighting in the final examination.

The aim of this study was informed by the reported failure of professional development initiatives to shape teaching practices and improve learners' academic achievement (Kraft et al., 2018). The implication of Kraft et al. (2018) findings was that the effectiveness of professional development initiatives must be examined while they are underway, making room for timely adjustments to be made, when necessary. Since the blended professional development intervention model being examined by this study was in the pilot stage, the examination of its effectiveness in shaping teaching practice was fundamental. This is because such examination would provide insight about the intervention on areas of improvement to ensure that the adopted professional development model promotes change in teaching practice. Therefore, this study bridges the identified gaps in research by examining the effectiveness of the administered professional development intervention in changing the teaching practices of novice Physical Sciences teachers in rural schools within the Mpumalanga province, thereby providing a framework for effective blended professional development. This study intended to address the following research questions:

How effective was the blended professional development *intervention in improving the teaching practices of novice Physical Sciences teachers in rural schools of Mpumalanga province?*

To answer the research question above, the following sub-questions were addressed:

1. What are the teaching and learning needs of novice Physical Sciences teachers in the rural schools of Mpumalanga province?
2. What are the views of the novice Physical Sciences teachers about the effectiveness of the blended professional development intervention workshops?
3. In what ways have the teaching practices of Physical Sciences novice teachers changed after participating in a blended professional development intervention?
4. How were the identified teaching and learning needs of novice Physical Sciences teachers in the rural schools of Mpumalanga addressed by the blended professional development intervention?

This study focused on novice teachers only, that is, teachers with less than five years of experience teaching Physical Sciences in Grade 12. The novice teachers were selected because research shows that these teachers often experience 'transfer shock', which stimulate stress, burn out, often leading to poor learner performance (Caspersen & Raaen, 2014). In rural schools, this is further exacerbated by the shortage of teachers (Masinire, 2015), resulting from lack of mentors who can induct them into the profession and assist them with the transition. Furthermore, members of the SMT do not have the relevant knowledge and skills to support these teachers (Ntsoane, 2017). As such, they are vulnerable and in most need of support. From those teachers who participated in the professional development intervention, only five had less than five years of teaching experience in Physical Sciences. However, one of these teachers withdrew her consent to participate in this study while the other one was on maternity leave, leaving only three teachers with less than five years of experience in teaching Physical Sciences. Therefore, this study consists of three novice Physical Sciences teachers.

Lesson observations and semi-structured interviews were conducted with the teachers and used as data sources to answer the above research questions. This data was collected before and after the teachers participated in the professional development intervention. Field notes were also written for every workshop of the intervention. To answer the first research question, the collected data was categorised into two major themes: classroom efficacy and professional efficacy. The classroom efficacy theme had four sub-themes (comprehension, content representation, instructional selection, and adaptation of content) that were adopted from Mushayikwa and Mushaikwa (2023) and used to further categorise the data.

Professional efficacy has three sub-themes (classroom management, professional identity, and professional integrity) that were also adopted from Mushayikwa and Mushaikwa (2023) and used to further categorise the data. Triangulation of data methods and data sources was used to analyse and make sense of the data as described in Chapter Six, Section 6.2.1. The identified needs of the teachers per theme and sub-theme were used to guide the analysis of the post-intervention data to answer the fourth research question of this study. It is important to note that teacher efficacy, classified into classroom efficacy and professional efficacy were not only brought in to analyse the data, but it also served as a conceptual framework for this study.

To answer the second research question, thematic analysis was employed. In this analysis approach, patterns were identified and categorised into themes from the interviews. Thereafter, triangulation of data sources, as illustrated in Figure 14, was used to support the generated meanings. For the third research question, triangulation of frameworks to analyse the data. triangulation of frameworks involved the integration of the pedagogical link making (PLM) framework, and the semantic codes of legitimation code theory (LCT) framework resulting into codes being developed and used to analyse and interpret the lesson observation data. The PLM and LCT framework were also part of the conceptual framework of this study, in addition to teacher efficacy.

11.2. SUMMARY OF THE FINDINGS

The findings of this study showed that teachers had low classroom efficacy in terms of comprehension emanating from language issues. These teachers showed lack of awareness of the value of non-technical terminology in the learning process. As such, non-technical terms were usually unpacked.. The value of non-technical terms and how to address them in a lesson was touched upon during the intervention. The teachers a did not understand that some science concepts are used in various contexts with similar or different meaning as that in science as they seem believe these can be taught once in earlier grades. However, few instances of integration and differentiation were observed where the teacher was helping the learners with these concepts. These instances were the result of the teachers critically reflecting on the interview questions as such concepts were explained during the interviews, and yet not addressed in the intervention. This was particularly the case with Mr Jones who did not use integration or differentiation in his pre-intervention lessons.

The teachers have also displayed low classroom efficacy in representing Chemistry content. The teachers also indicated that that it is not easy to find analogies and examples that learners could relate to in Chemistry. Although some of the workshops were focused on Chemistry topics, the teachers still not confident to teach Chemistry. This was particularly evident in all the teachers, including Mr Jones who taught Chemistry topics only for all his classroom observations, in which instances where he used analogies and relatable examples were low and remained unchanged even after participating in the intervention. These teachers are also experiencing the same challenge in some topics of Physics, especially in the Electricity topic, and in the Photoelectric Effect topic which has the same level of abstractness as Chemistry topics. Although these teachers may not have gained the needed support in presenting content, especially in Chemistry, they still learned some strategies on presenting content in general. They also learned new strategies that they can use to prepare their learners for examination, increasing their pass rate.

Low classroom efficacy in content representation was also advanced by learners' limited proficiency in the LOLT. During the lessons, learners were allowed to use their home languages to engage with the teachers. Moreover, the teachers often used code switching in their lessons.

Such occurrences were observed before and after the teachers participated in the professional development intervention.

Two of these teachers, Mr Brown and Mr Jones, received micro-kits to use when teaching Chemistry and Physics demonstrations/experiments. However, it was apparent that the teachers did not know how to improvise when one of the apparatuses was not working. This is because they did not know how to conduct any other experiment except for the ones prescribed by the curriculum. Furthermore, these teachers had a limited view of the effectiveness of experiments in promoting conceptual understanding. Their views about experiments, including Mr Smith's, were limited to a macroscopic level, indicating that they do not know how to relate macroscopic observations to the microscopic and symbolic level. Although this knowledge was implicitly shared with the teachers in one of the workshops about Rates of Reactions, the teachers' lack of change in perspective indicates that this was insufficient, especially since it was illustrated with one of the topics they did not identify in Figure 11 as challenging to teach.

The study found that these teachers also had low classroom efficacy with regards to adapting instruction to meet the specific learning needs of their learners, leading to extended teaching times. This was caused by lack of lesson planning and reflection. Despite the importance of planning and reflection in teaching, these teachers believed that their experience negated the need for such critical preparation. Although reflection templates were provided, they were not utilized effectively for development purposes. Furthermore, the teachers were passive participants during the intervention, receiving no feedback or guidance to enhance their planning, in general and per topic, and reflection skills. However, the teachers did learn about misconceptions and misunderstandings that learners may develop and ways of addressing them in each of the topics they were workshopped on. Such knowledge will aid the teachers in effectively transforming SCK into comprehensible concepts, efficiently reducing the amount of time they spend at school repeating the same thing several times. While Mr. Smith believed both every day and scientific meanings of terms were presented, the workshops focused on defining the main concepts per topic as required by the curriculum. Overall, the workshops offered strategies for adapting content to student needs, though there were areas for improvement in ensuring successful implementation of these strategies through careful planning, reflection, and feedback.

In terms of professional efficacy, these teachers did not know how to select good quality textbooks for their learners which is part of classroom management. Their schools also lack adequate textbooks. Although the teachers did not receive assistance on the selection of quality textbooks or additional textbooks, they found the teaching and learning materials provided by the intervention helpful in addressing the shortage of textbooks. In addition to the strategies shared during the intervention, the teachers revealed that these materials played a role in boosting their confidence.

This study noted that teachers spend excessive hours teaching, including weekends. This is due to the shortage of teachers to share their teaching load with, especially in School A and B. As such, Mr Jones has requested an extra teacher for assistance. Mr Brown expressed the need for external facilitators to conduct extra classes on weekends and holidays, allowing them time to reboot. Teachers have also expressed a desire for practical demonstrations of the implementation of the shared teaching methods. This need was fulfilled as the facilitator visited Mr Brown's school and taught his learners while he and the other teachers observed. Teachers praised this method, suggesting its continued adoption in the future. Furthermore, this strategy was used to aid School D, where each teacher was given a topic to teach to the learners.

With regards to professional identity, the study revealed that teachers participated in the intervention with the purpose of achieving a 100% pass rate in their subjects. The intervention appeared effective for many teachers, including Mr. Brown and Mr. Jones, who reported improvements in their learner performance as well as confidence in teaching the subject. In addition, Mr. Brown benefited from networking opportunities, while Mr. Jones gained valuable insights on challenging topics from an experienced facilitator, thereby enhancing their professional identities and efficacy. Mr Smith also benefitted from the individual support he received on the face-to-face workshops during breaks by chatting with the facilitators.

However, the intervention fell short in helping Mr. Smith establish his professional identity as a Physical Sciences teacher. This is because the shared strategies did not yield positive results for Mr. Smith as his learners continued to perform poorly. Although he attributed his learners' poor performance to their lack of commitment, revealing a potentially negative attitude towards certain learners, his lack of qualification in Physical Sciences may be the major attribute to the persisting poor performance of his learners. Furthermore, he needs more professional development in Chemistry, hence he attended workshops of Chemistry topics only. However, he has not been teaching Physics as well for over fourteen years and may not have adequate PCK to teach it since it is not his subject of specialisation.

In terms of professional integrity, the study found out that all teachers preferred to Physics to Chemistry. However, Mr Brown and Mr Smith were observed teaching Chemistry topic(s), while Mr Smith exclusively taught Physics topics during classroom observations before and after the intervention. This does not imply that Mr. Smith is not teaching Chemistry; rather, his focus on Chemistry workshops indicates ongoing development in this area. Therefore, additional workshops focusing on Chemistry could enhance his and Mr. Jones' teaching capabilities, as both are teaching out of their field of specialisation. Such workshops would also benefit Mr. Brown, who has low classroom efficacy in teaching Chemistry.

Although this blended professional development offered flexibility as one could attend anywhere, this study found that teachers preferred the face-to-face workshops over the online workshops, especially Mr Brown. Teachers raised issues of costly data bundles and poor network coverage causing poor internet connection as having major influence on their attendance in online workshops. This may have also impeded their opportunities for one-on-one consultations with the facilitators, as they noted that individual support was lacking in online workshops. However, the teachers did note how they could join the online with their learners while that is not possible in face-to-face workshops. In addition, the online workshops were recorded, and the recordings were made available to the teachers. This study, however, found that teachers did not use the recordings which would have helped them with the content covered during those workshops they missed. They were also not actively participating in the WhatsApp group which was established to promote collaboration and offer support beyond workshop hours.

The other reason for not preferring online workshops is that they do not promote active engagement. The teachers noted that they were easily distracted during online workshops and sometimes they may appear to be present while they were attending to other things unrelated to the workshop. This was because they were expected to turn off their cameras and mute their microphones during the online workshops. With these turned off, no one could see what the teachers were up to. Furthermore, there was limited active engagement during the workshops because the facilitators addressed the teachers most of the time while the teachers would occasionally answer questions.. This lack of active engagement made teachers prone to sleepiness and distractions. Moreover, some of the topics that majority of the teachers identified as challenging and needing professional development on were not addressed during the intervention. Hence, the teachers may have found the intervention irrelevant to their needs.

The abovementioned challenges that were experienced by the teachers during intervention workshops, online workshops, are the prime reasons why there was limited change in the teaching practices of these teachers and continued challenges around the teaching of Chemistry. The only change observed in the teaching practices of these teachers was emphasis on how learners could earn marks in their examination which was based on the explicit guidance given during the intervention workshops. However, there was no change in the way the teachers were delivering instruction with regards to SCK. Mr Jones showed little awareness of language issues gained from reflecting on the interview questions.

11.3. CONCLUSION

This study has shown that the blended professional development intervention failed to change the teaching practice of the novice teachers. The lack of improvement in the teaching practice of the teachers is primarily attributed to the poor design of the blended professional development intervention. For example, teachers were not given authentic activities to complete to promote active engagement with content, neither were they coached/mentored on the effective implementation of the shared strategies. Active interaction was also not promoted in the WhatsApp group to establish a community of practice. Furthermore, most of the identified teaching and learning needs of the teachers were not addressed. For example, while teachers needed support on the teaching of the Electricity topic, they were workshopped on the Electrodynamics topic. Moreover, teachers' access to online professional development workshops was not supported through the provision of necessary digital resources/tools, such as internet data. Lack of digital tools to access online workshops influenced teachers' attendance. Even when teachers were present, it was impossible to verify that they are paying attention.

Therefore, for blended professional development to shape the teaching practice of the teachers, it must comprise some of the tenets for face-to-face professional development presented in Figure 2. In other words, it must be content focused, coherent, sustainable, and promote active engagement and collaboration (Desimone, 2009; Patton et al., 2015). Blended professional development must also be of longer duration, with at least twenty hours spent developing the teachers (Desimone, 2009; Patton et al., 2015). It must also encourage independent learning which is carefully guided as teachers often experience time constraints (Hunt-Barron et al., 2015; Tsiotakis & Jimoyiannis, 2016). Provisions must also be made for individual support, online and offline. This aspect with address teachers' desire for privacy (Hunt-Barron et al., 2015), allowing any teacher who may not be comfortable sharing their concerns on a public space to be supported. Teachers must also be given necessary tools that enable access to the online component of the professional development (Mukuna & Aloka, 2020). Since this professional development initiative involves an online component, the organisers and facilitators must have adequate TPACK to be able to effectively integrate technology into teachers' professional development to promote rich online learning experiences (Powell & Bodur, 2019). In other words, it must meet all the tenets of a blended professional development outlined in Figure 4 to be able to shape teaching practice.

Although the intervention failed to change the teaching practice of these teachers, it was able to improve the performance of their learners, unlike those studies reviewed by Kraft et al. (2018). The improvement in performance was because of the implemented strategies that were targeted to this aspect. Teachers in this intervention were workshopped on how to teach various topics and how to improve learner performance. In other words, improvement in the performance of the learners was not expected to be a *byproduct* of a change in teaching practice. Researchers see improved learner performance to be the consequence of improved teachers' practice (Darling-Hammond et al., 2017). This view of professional development results into a development of interventions that are solely focused on improving teaching practice without addressing learner performance. Since improved learner performance is the prime motivation for teachers to engage in professional development (Letloenyane & Jita, 2020), it is therefore fundamental that this aspect be directly addressed by professional development, instead of treating it as a byproduct of Improved teaching practice.

11.4. IMPLICATION OF THE FINDINGS

The study reveals several critical implications for the design and implementation of effective blended professional development for novice teachers. Here are the suggested implications for improving teacher professional development:

Content Focus and Relevance:

Professional development initiatives must align with the specific teaching and learning needs of the teachers. In this study, the misalignment between the workshop content (Electrodynamics) and the teachers' needs (Electricity) hindered effectiveness. Future teacher professional development should ensure the content is directly applicable and relevant to the teachers' current teaching and learning challenges.

Active Engagement and Authentic Activities:

Incorporate authentic, practical activities that promote active engagement with the content. This can include planning a lesson on topics identified to be challenging to encourage teachers to apply the acquired knowledge in their lessons.

Encourage active interaction and collaboration through online platforms. For instance, using WhatsApp to foster a community of practice where teachers can share experiences, ask questions, and receive feedback. Importantly, facilitators must come up with different ways to help teachers establish a conversation, this could be through posing a teaching and learning related question. However, it should not be expected that teachers will, on their own, establish these conversations.

Coaching and Mentorship:

Provide continuous coaching and mentorship to support the effective implementation of the learned strategies. Personalized feedback and one-on-one mentoring can help teachers integrate new practices more effectively.

Adequate Resources and Access:

Ensure that teachers have access to the necessary digital resources, such as internet data and devices, to participate fully in the online components of blended professional development. Lack of access can significantly impede engagement and attendance. This aspect is fundamental in promoting equity and access to resources and quality education, particularly for teachers in rural schools. This is because these teachers would want to use professional development as an opportunity to access resources, thereby improving the quality of their teaching practice, consequently, changing the status quo of education in rural schools being associated with poor quality as van Dyk and White, (2019) reported. Therefore, the importance of access to digital resources should not be undermined in the design of blended teacher professional development.

Duration and Sustainability:

Professional development programs should be of sufficient duration, ideally at least twenty hours, to allow for meaningful development and practice of new skills. Short-term workshops are less likely to result in lasting changes in teaching practice. Since this has implications for funding, partnership with the relevant education institutions must be forged to enhance the sustainability of teacher professional development initiatives.

Coherent and Integrated Approach:

The professional development should be coherent, with a well-structured curriculum that builds on prior knowledge and integrates various aspects of teaching practice. A cohesive approach helps teachers make connections between different concepts and strategies. However, this approach needs to be mindful of the challenges and opportunities offered by the rural context.

Independent Learning and support:

Encourage independent learning that is carefully guided, providing flexibility for teachers who may face time constraints, especially those who are teaching Grade 12. In addition, allow for individual consultations to support teachers who may not feel comfortable sharing concerns in public forums, particularly those who are novices and/or teaching out-of-field.

Technology Integration:

Ensure that professional development facilitators possess plausible Technological Pedagogical Content Knowledge (TPCK) to effectively integrate technology into teacher professional development. This ensures that the online learning experiences are enriching and aligned with the overall educational goals.

Focus on Learner Performance:

While improving teaching practice is essential, professional development initiatives should also directly address strategies to enhance learner performance. Given that teachers are primarily motivated by improving student outcomes, this dual focus can increase their engagement and commitment to the professional development.

By incorporating these components, blended professional development can be more effective in shaping teaching practices and ultimately improving both teacher performance and student outcomes. It is important to note that these components are also applicable to traditional and online teacher professional development initiatives. These components will also contribute significantly to the self-efficacy of the teachers, empowering them to engage in self-directed professional development.

11.5. STUDY CONTRIBUTION TO THEORY AND PRACTICE

Although this study used a limited sample size, it highlights key features that must be considered in enhancing the effectiveness of teacher professional development. This was not limited to the ones that have been identified by literature, it also highlighted the importance of facilitator's expertise in the shaping of teaching practice. In this study, for example, Mr Jones appreciated the experience the facilitator, Dr Davis, was bringing, making it easy for him to use the knowledge she was sharing. This revealed that teachers value the input of their facilitators due to their level of expertise in the field. Hence, this study concurs with Perry and Booth (2024) that the value of facilitators in the effectiveness of professional development should not be undermined. Therefore, more research into the role of facilitators and their expertise is required to better understand the extent of their influence in teacher professional development.

Since this study focused on blended professional development, teacher expertise was not limited to years of teaching experience. It included the facilitators' technological pedagogical content. This was evident in the findings of this study where lack of active engagement with the teachers was observed, particularly during online workshops resulting into these teachers falling asleep and attending to other tasks not related to the workshop. Therefore, this study highlights methods in which blended professional development can be designed and facilitated to actively engage the teachers, and ultimately, shaping their teaching practice.

This study has also highlighted the challenges of teaching and learning faced by novice teachers in rural schools. Due to the diverse nature of the novice teachers who participated in this study, more challenges into rural school teaching were revealed. This includes the challenge of out-of-field teaching, and the various challenges off-field teachers face in teaching Physical Sciences. Based on the observed challenges, this study has emphasised the importance of individual support, and a deeper focus into enhancing teachers' SCK and PCK per topic.

This study has also conceptualised a framework, see Figure 4, that can be used to aid the teachers' classroom and professional efficacy. Although the framework has been developed from the reviewed literature, the significance of each component in the effectiveness of a professional development initiative has been highlighted in the findings of this study. Such a framework, therefore, will play an important role in the design, implementation and conceptualisation of teacher professional development initiatives.

This study has also highlighted the need to address learner performance as a separate entity in teacher professional development rather than a *byproduct* of improved teaching practice as viewed by researchers, such as Darling-Hammond et al. (2017). Viewing improvement in learner performance as a byproduct of changes in teaching practice limits professional development initiatives into focusing solely on improving teaching practice while neglecting learner performance. Such a neglect may influence teachers' participation into any professional development activities since Letloenyane and Jita (2020) has reported that teachers seek professional development to mainly improve learner performance. This study has evidently shown that explicit focus on learner performance during teacher professional development can yield the required outcomes. This finding provides an insight into approaches that can be used to prevent the observed failure of professional development initiatives to improve learner performance as reported by Kraft et al. (2018).

11.6. RECOMMENDATIONS

This study recommends that further research be conducted with larger sample sizes where the effect of integrating improvement of learner performance into the professional development of teachers is investigated. These studies should focus on different cases, such as novice and off-field teachers with various years of teaching experience. Such a focus will bridge the gap in research of professional development intervention failing to improve learner performance as Kraft et al. (2018) observed.

This study also recommends that the proposed framework in Figure 4 be empirically implemented to determine the extent of its effectiveness in shaping the teaching practice of teachers and improving learner performance. These studies are highly recommended in rural schools as they are severely disadvantaged with limited research focus (Nkambule et al., 2011; Zulu, 2018). Such research will contribute to knowledge on blended teacher professional development in terms of best practices to enable a change in teaching practice and improved learner performance. They will also address the dearth in research on rural schools.

This study also recommends a bridge into the gap of research related to facilitators in professional development as Perry and Booth (2024) have reported. Perry and Booth (2024) had revealed that the role of facilitators in professional development has been undervalued. Thus, there is a need for further research into facilitators. Such research should highlight the significance of facilitators in professional development, the role they play in the effectiveness of the professional development and the type of expertise they should possess.

Oyoo and Nkopodi (2020) recommended that teachers be professionally developed on improving learners' proficiency in the science language. However, there is dearth of research on how this can be executed. Therefore, this study recommends that further research be conducted to determine effective practices that can be used to address the linguistic needs of the teachers for the benefit of their learners and incorporate them into teacher professional development initiatives.

Lastly, a policy detailing the identified effective professional development components as compulsory constituents of any teacher development initiative should be established. In addition, centralised structures, similar to ethics committees, should be put in place to assess the design of any proposed professional development initiatives before it can be implemented. Such assessment should be guided by the policy, looking at how each of the identified effective professional development components are incorporated in the design and how they will be facilitated to shape practice. This would set the standard for professional development initiatives and ensure compliance as well as awareness of research trends in professional development. Furthermore, evaluation and progress reports of the initiatives should be submitted to the established structures. This would also ensure that teacher professional development initiatives are governed and held accountable. It would also ensure that facilitators do not solely hold the decision-making power about the activities and constituent of the professional development initiatives. This would reduce the failure of professional development initiatives to meet their intended outcomes as reported by Kraft et al. (2018) and observed in this study. However, the policy should be open to revisions as more evidence of further components to enhance the effectiveness of professional development initiatives is brought forward. This study acknowledges that the abovementioned features of teacher professional development will not necessarily guarantee success, however, they have the potential to shape teaching practice provided they are implemented and facilitated strategically.

11.7. LIMITATIONS OF THE STUDY

Due to the small size of the sample of this study, these findings cannot be generalized to the entire population involved in the professional development intervention. This is further limited by the diverse nature of the cases, with some teachers being novices and teaching their subjects of specialisation while others are teaching out of specialisation with little to more years of experience in the profession. Therefore, these findings are specific to the participants that were involved in this study. However, these findings may be similar to other cases of novice and/or off-field Physical Sciences teachers who participated in the professional development intervention. They may also be relatable to other studies on teacher professional development (face-to-face, online or blended) initiatives that are focusing on rural contexts.

Further engagement with the findings revealed in this study was limited by the focus on novice teachers only. An extension of this study to the facilitators, participating officials from Mpumalanga department of education and all members of the intervention could have shared more light in some interesting observations and findings. For example, the participation of facilitators could have shared more light into the extent in which each of the identified feature of effective professional development was implemented with supporting reasons for all the choices made about the intervention workshop as well as the overall professional development support for the teachers. This would provide a detailed explanation of the observed lack of active engagement in workshops and limited use of the WhatsApp group to facilitate teachers' professional development.

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Appendix A: Ethics Clearance Certificate

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Research Office

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

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H21/05/43**
PROJECT TITLE	Investigating the impact of a professional development intervention on the teaching of Physical Sciences: A study of Novice and Out-of-field teachers in South African rural schools
INVESTIGATOR(S)	Ms N Radebe
SCHOOL/DEPARTMENT	Education/
DATE CONSIDERED	21 May 2021
DECISION OF THE COMMITTEE	Conditionally Approved Permissions letters are required from GDE and the schools before data collection can commence Risk Level: Low
EXPIRY DATE	17 June 2024

DATE 18 June 2021 **CHAIRPERSON** J-Knight

(Professor J Knight)

cc: Supervisor : Dr E Mushayikwa

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to submit an amendment of the protocol to the Committee. **I agree to completion of a regular progress report. For Minimal and Low studies, this is due annually on 31 December. For Medium and High Risk studies, this is due twice annually on 30 June and 31 December.**

N.K. Radebe. 06 / 07 / 2021

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix B: Mpumalanga Department of Education Approval Letter

education
MPUMALANGA PROVINCE
REPUBLIC OF SOUTH AFRICA

Ikhamanga Building, Government Boulevard, Riverside Park, Mpumalanga Province
Private Bag X11341, Mbombela, 1200
Tel: 013 766 5552/5115, Toll Free Line: 0800 203 116

Litiko le Temfundvo, Umnyango we Fundo | Departement van Onderwys | Ndzawulo ya Dyondzo

Nomfundo Radebe
27 St Andrews Road
Parktown, Johannesburg
Email: knowmfundo@gmail.com
Cell: 064 439 0086

RE: INVESTIGATING THE IMPACT OF A PROFESSIONAL DEVELOPMENT INTERVENTION ON THE TEACHING OF PHYSICAL SCIENCE: A STUDY OF NOVICE AND OUT-OF-FIELD TEACHERS IN SOUTH AFRICAN RURAL SCHOOLS

Your application to conduct research study was received and is therefore acknowledged. The tittle of your research project reads: **"Investigating the impact of a professional development intervention on the teaching of Physical Science: a study of novice and out-of-field teachers in South African rural schools".** I trust that the aims and the objectives of the study will benefit the whole department especially the beneficiaries. Your request is approved subject to you observing the provisions of the departmental research policy which is available in the department website. You are requested to adhere to your university's research ethics as spelt out in your research ethics.

In terms of the research policy, data or any research activity can be conducted after school hours as per appointment with affected participants and COVID -19 regulations to observed. You are also requested to share your findings with the relevant sections of the department so that we may consider implementing your findings if that will be in the best interest of the department. To this effect, your final approved research report (both soft and hard copy) should be submitted to the department so that your recommendations could be implemented. You may be required to prepare a presentation and present at the departments' annual research dialogue.
For more information kindly liaise with the department's research unit @ 013 766 5124/5148 0r nmadihlaba@mpuedu.gov.za
The department wishes you well in this important project and pledges to give you the necessary support you may need.

Moyane

MRS LH MOYANE
HEAD: EDUCATION

21 / 06 / 2021
DATE

MPUMALANGA

Appendix C: Schools' Information Letters

Dear Principal and SGB Chair

My name is Nomfundo Knowledge Radebe. I am a Doctoral student in the School of Education at the University of the Witwatersrand.

I am doing a research study titled "*Investigating the impact of a professional development intervention on the teaching of Physical Sciences: A study of Novice and Out-of-field teachers in South African rural schools*". The study is part of a larger research study that will be administering an intervention aimed to professionally develop Physical Sciences teachers and improve learners' performance. The intervention is a joint collaboration between the Mpumalanga Department of Education and the WITS School of Education focusing on novice teachers (beginning teachers with less than five years of teaching experience) and out-of-field teachers (teachers who are teaching subjects/level of study they are unqualified to teach) teaching Physical Sciences.

By conducting this study, improvements can be made in the intervention to ensure that it improves the teaching practices of Physical Sciences novice and out-of-field teachers. Therefore, the purpose of this research study is to investigate ways in which the teaching practices of Physical Sciences novice and out-of-field teachers has changed after participating in the intervention.

To determine how the teaching practices of novice and out-of-field teachers has changed after participating in the intervention, video recorded classroom observations will be made. These observations will be made before and after the teachers participate in the intervention. Two lessons will be observed before the teachers participate in the intervention. Two more lessons will be observed after the teachers have been exposed to the intervention. A total of four lessons per teacher will be observed. In addition to video recorded observations, audio-recorded interviews will be conducted with the teachers. The teachers will be individually interviewed before and after participating in the intervention.

Where physical interactions are restricted due to the COVID-19 pandemic, teachers will be requested to video record their own lessons. They will be requested to video record two of their Physical Sciences lessons before participating in the intervention. They will be requested to video record two more Physical Sciences lessons after they have participated in the intervention. The teachers will be instructed on how to encrypt the data as they share it with me using Google Drive to restrict access to it. After the data has been shared with me, all features that may be used to identify the teacher, his/her learners and the school will be removed. The data will then be stored in a password protected computer where only me and my supervisor will have access to it.

In addition to video recorded lessons, online interviews through Microsoft Teams will be conducted with individual teachers where physical interactions are restricted due to the COVID-19 pandemic. One online interview will be conducted with individual teachers before they participate in the intervention. One more online interview will be conducted with individual teachers after they have participated in the intervention. These interviews will be recorded, and the recordings will be kept in a password protected computer with restricted access. Also, any features that may be used to identify the teachers and their schools will be removed from the data.

The reason why I have chosen your school is because the novice and/or out-of-field teacher(s) who are voluntarily participating in the intervention and this study are currently employed in your school. I need to observe how the teaching practices of these teachers has changed after participating in the intervention.

I am kindly requesting permission to conduct this research study in your school. Your permission to conduct this study will help me fulfil my requirements for the Doctoral degree. It will also provide the intervention with an insight regarding its impact on the teaching practices of novice and out-of-field teachers. This study will provide data that will ensure that adjustments that will address teachers' concerns and improve their teaching practices are made on the intervention in time. Thus, improving the experience of the teachers.

While observing the teachers in their classrooms, learners will also be observed. As such, their consent to be video recorded will be sought. Where physical interactions are restricted due to COVID-19, I will kindly request the teachers to invite their learners to participate in the study on my behalf, by asking them and their parents/guardians to sign informed consent forms. The learners will not be advantaged or disadvantaged in any way. Nonconsenting learners will not be observed or video-recorded although they will be expected to participate in class as required by their teacher and school. All participants (teachers and their learners) will be reassured that they can withdraw their permission at any time during this study without any penalty. There are no foreseeable risks in participating in this study. The participants will not be paid for participating in this study.

All names of participants and the school will be kept anonymous. The identity of the school, teachers and that of individual participants will not be revealed, instead pseudonyms will be used to identify individual participants where names are necessary. In addition, any symbolic representations and participants' faces will be blurred to protect their identity and that of the school. Data obtained from the study will be kept safe and confidential and my supervisor and I will be the only individuals who will have access to the data.

All research data will be destroyed between 3-5 years after completion of the project.

Please let me know if you require any further information. I look forward to your response as soon as it is convenient.

Yours sincerely,

Nomfundo Radebe

Signature: N.K. Radebe.

Address: 1600 Nkelenga Road Lufhereng Ext. 1, Soweto, 1863

Email: knowmfundo@gmail.com/851590@students.wits.ac.za

Telephone numbers: 0644390086

Appendix D: Teachers' Information sheets

Dear Sir/Madam

My name is Nomfundo Radebe, and I am a doctoral student in the school of Education at the University of the Witwatersrand, Johannesburg. As part of my studies, I have to undertake a research project, and I am investigating the impact of the joint collaboration intervention aimed to professionally develop Physical Sciences novice teachers (beginning teachers with less than five years of teaching experience) and out-of-field teachers (teachers who are teaching subjects/level of study they are unqualified to teach), under the supervision of Dr Emmanuel Mushayikwa. The aim of this research project is to investigate ways in which the teaching practices of novice and out-of-field Physical Sciences teachers has changed after participating in the intervention.

As part of this project, I would like to invite you as a novice Physical Sciences teacher to take part in an interview before and after participating in the intervention. This activity will involve answering questions face to face (or on Microsoft Teams in case of stricter COVID-19 lockdown regulations) with me about the way you teach Physical Sciences. Each interview will take about 30 minutes. With your permission, I would also like to observe two of your Physical Sciences lessons before participating in the intervention and two more after participating in the intervention. I would also like to audio record the interviews and video record the lessons I will be observing using a digital device with your permission. In case of stricter COVID-19 lockdown regulations, I would like to invite you to video record your lessons and electronically share the recordings with me. You will be informed how to protect the recordings as you electronically share them with me.

There may be a personal cost to participating in this study, especially when stricter COVID-19 lockdown regulations are in place, where you may need to buy data bundles to partake in an online interview and use it to electronically share the recordings with me. You will not receive any direct benefits for participating but the findings of this project will be used to ensure that adjustments that will address your concerns and improve your teaching practices are made on the intervention in time. Thus, improving your experience of the intervention.

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 and lesson observations 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 except my supervisor. I will be using a pseudonym (false name) to represent your participation in my final research report and your face will be hidden in all the recordings. If you experience any distress or discomfort at any point in this process, we will stop the interview and/or observations or resume another time.

If you have any questions during or afterwards about this research, feel free to contact me on the details listed above. 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 a password protected computer and will be destroyed after 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,
Nomfundo
Researcher's supervisor:
Dr Emmanuel Mushayikwa
011 717 3249
emmanuel.mushayikwa@wits.ac.za

Appendix E: Teachers' consent forms

Name of the researcher:	Nomfundo Radebe
Researcher's supervisor:	Dr Emmanuel Mushayikwa
	011 717 3249
	emmanuel.mushayikwa@wits.ac.za
Researcher's signature:	N.K. Radebe.
Date:	06 June 2021

I, …………………………………………………………., a novice Physical Sciences teacher 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 the interviews may be audio recorded	Yes	No
I agree that my lessons may be video recorded	Yes	No
I agree to video record my own lessons should stricter COVID-19 lockdown regulations be put in place and will share the data with the researcher.	Yes	No
I agree that my participation will remain anonymous	Yes	No
I agree that the researcher may use anonymous quotes in her research report	Yes	No
I agree that the information I provide may be used anonymously after this project has ended, for academic purposes by other researchers, subject to their own ethics clearance being obtained.	Yes	No
I understand that my participation in this project is voluntary, and I can withdraw from participation at any point without incurring any negative repercussions from the project	Yes	No

Name of participant: ……………………………………

Signature: ……………………………………

Date: ……………………………………

Appendix F: Pre-intervention Interview protocol

The aim of this interview schedule ways to determine novice teachers view' of their teaching practices. This interview schedule was enacted in Mpumalanga before the novice teachers participated in a blended professional development intervention.

Introductory questions:

- Where did you train to be a teacher?
- When did you qualify to be a teacher?
- What is your highest qualification?
- What were your subjects of specialization in your teacher training?
- What other subjects are you currently teaching?
- How long have you been teaching Physical Sciences?
- What other Grades are you teaching Physical Sciences to?

Research Interview Questions

- What do you think about Physical Sciences as a subject you are teaching?
- What do you enjoy/appreciate the most about teaching Physical Sciences? Why?
- What do you least enjoy about teaching Physical Sciences? Why?
- Is there anything you would like to change regarding how you are teaching Physical Sciences? Why or why not?
- Do you think scientific concepts are interlinked? Why or why not? How do you teach scientific concepts?
- When teaching Physical Sciences, do you link scientific explanations with real-world phenomena? If yes, do you use any representation to make the link explicit?
- Do you include analogies in your lessons? Why or why not?

- Concepts such as momentum bear different meanings to different contexts, how do you help learners to understand such concepts?
- Concepts such as resistance bear similar meaning to different contexts, how do you help learners to understand such concepts?
- Are you familiar with what is taught in NS (the physics component)? How have you integrated that content with your current grade?
- How often do you refer learners back to what they had learned earlier on during the lesson? Previous lesson? Previous Grade? Why?
- Does the frequency in which you refer learners back to what they had done earlier on differs with each component of Physical Sciences? Why or why not?
- How often do you engage learners in your lessons? Why?
- What challenges, if any, do you experience while teaching Physical Sciences?
- What do you hope to achieve by participating in the professional development intervention? Why?

That is all for today. Thank you so much for your time.

Appendix G: Pre-intervention Interview transcript

Participant pseudonym: Mr Smith **Interview date: 22 June 2021** **Interviewer: Nomfundo Radebe** **Interview duration: 43:06**	
Nomfundo	Tell me a bit about yourself.
Mr Smith	My name is Piet Smith, born 1976. I live at Area C, few kilometres from this school. I passed my matric in 1996, then I went to tertiary at the University of Limpopo. I studied BSc, majoring in Physics and Applied Mathematics. I came back, it was 2005 and I started teaching at School C, teaching Physical Sciences, grade 10 and 11. I started 2005, 6, 7, 8, 9, teaching the very same grades. Then in 2010 there, we introduced new phases to take Grade 12, but I was still teaching the Grade 10's and 11's up until…this is 2021. Then I came to teach grade 12 Physics in 2020. Ja, and then this year I am still teaching grade 12 Physics, and grade 10 Physics.
Nomfundo	Okay, then what is your highest qualification?
Mr Smith	It's Bachelor of Science. And the PGCE from Unisa.
Nomfundo	Oh, okay, so what were your subject specialisations?
Mr Smith	It was NS and Mathematics.

Nomfundo	Okay. And then what other subjects are you currently teaching? It's just Physics?
Mr Smith	Strictly Physics and Maths. As well as Maths Literacy.
Nomfundo	Oh, okay. So then since you've been teaching Physics for this long, what do you think about it as a subject?
Mr Smith	Ja, Physics, it's not like any learning area. It's more of an abstract subject. Which if a learner opts to follow that route, the learner must be gifted mathematically. The learner must be able to interpret scenarios. And if given a formula the learner must know exactly what quantity to use, where to substitute, use a correct unit, things like that. So, in fact the learner must have the basic background from the lower grades. If say a learner was just introduced to grade 10, and choose to take science because somebody said, no, there's money in here, without the proper background, that's where we encounter a lot of problems. Because you find a learner cannot differentiate, for example, a vector and a scalar, those are the basics. So, it becomes a problem. And there are many issues…ja, there are many issues. In other cases, isn't that these people they will say, you cannot choose a learning area for a learner, the learner has a right, but you can see the potential it's not there, but you as a teacher, you…
Nomfundo	There's nothing you can do.
Mr Smith	You have nothing to do. So, you have to fight and struggle and try to implant that knowledge so the learner might think the other way around. Ja, Physics…generally it's not a difficult subject, but they need dedication.

Nomfundo	Ja, well said, Meneer. So, what do you enjoy about teaching Physical Sciences? What do you enjoy the most about the subject itself?
Mr Smith	With Physics what I enjoy the most, there's not a lot of explanations. In a definition, for example, it explains itself. The minute you put forward that definition, you take those key words, you are done; the rest that will follow…that definition is in a formula, so it's not a lot of work there. It's just that our learners need to be taught those Physical Sciences jargon. Ja, that's where they confuse…what do you call it…each subject has its own language. Ja, so if learners can be taught from the early stages, I think they can get better results. So, Physics, generally it's not difficult, it's not difficult. Though what we usually encounter, you find that a teacher…well it's normal, you specialised in Physics, strictly Physics, and then somebody specialised in Chemistry, and when you come to the field here, they say you are a science teacher but your specialisation it's one-sided. So that's why we'll find that maybe you are strong in paper one. At some stage you don't have an interest in Chemistry. At some stage you don't have an interest in Chemistry. That's where problems start to emanate. But if you are passionate about the subject, you go to the next person, they'll shed some light. From there you master the subject.
Nomfundo	Ja. So, since you did BSc and Physics, have you may be experienced challenges with regards to the Chemistry component? Teaching it
Mr Smith	…Ja, there was…when was it? There was a section in acids and bases…ja, in the earlier years when I started teaching Physics, ja, that section I used to call someone to come and assist. Gradually I learned. Because those they were the basics from the…during our matric, we used to learn the very same. But what was worse, this thing of saying this teacher is good in paper one, he will make sure he only teaches paper one the whole year. So, when you go to tertiary you

	don't have an interest in Chemistry. So, but when you come back you have no choice. You have to learn that section until you master. So, from that point I realised that even if you compare, Chemistry it's not difficult, it's just that a learner must be able to read directly from the textbook, because the knowledge is there. Unlike Physics, once you understand the concept, you bring in any scenario, you just apply.
Nomfundo	Okay. So, is there may be anything when you are teaching Physics, that you'd say you least enjoy it when you are teaching the subject?
Mr Smith	Normally with Physics I don't have any section that I will say, no, I hate this part. No.
Nomfundo	It's just Chemistry. It used to be that part.
Mr Smith	Chemistry was the bit of a section. But as we're now, I think it's the so-called a cluster group, because during team teaching, then it's simple, what was a troubled section, somebody will come and then teach his own technique, and even now technology is more advanced, you approach video lessons, it's easy this way these days unlike those previous years. So, it's not a challenge.
Nomfundo	Okay. Maybe then with the way you are teaching at the moment, is there may be anything that you think maybe I could change this…with the way you are currently teaching? Is there anything that maybe you'd like to change?
Mr Smith	That question…it's only if you observe. After observation then you can say, okay, I've realised this point there, what if we do this way? Because at the point, I cannot say in this section I should have done this. They will say no. Since you knew, what you need to change…ja, I think through observation then

	that can maybe share some light, say, no, there was a better way of presenting this part. You should have done, 1, 2, 3. Then we debate on that one.
Nomfundo	So then how often do you always reflect on your lesson?
Mr Smith	The only way that I only use, after teaching, there must be some formal work or informal work. Then that will guide me whether the people have understood the section. Then through writing those activities, that's the only way to gauge. Because if you keep teaching and there's no work, there's no way you can assess and you can't wait whether you have taught it the correct way, whether the learner has understood. So, it's the only measure, give them a test work, and formal or informal…ja.
Nomfundo	So then when you are teaching Physics, which includes also Chemistry, you know that Physics concepts, it's not just one concept, you know, they are always linked to each other anyway. So how do you help learners…do you make them see that these concepts are actually linked?
Mr Smith	You mean like…
Nomfundo	Like for example when you, let's say you are teaching momentum, you'll always have to go back to vectors, you see, so those links, showing that the concepts are linked.
Mr Smith	Ja, ja…that's why I always tell these learners, that you cannot divorce mathematics from Physics. You cannot divorce Physics from geography. Those learning areas, they are interlinked. Because once I introduce vectors, obviously I will talk about direction there. And then the learner must know, if let's say an object, it's moving towards east, that's geography, you must know.

	How, if you draw a sketch, you must indicate. So those subjects are linked. So, you cannot divorce one subject to the other. The other day I was telling this tourism teacher, saying when we talk of currency, saying that these learners you have taught them the currency changes when you go to Europe or whatever, whatever, the same topic is also in Maths. But when you get there the learner will say, no, this is not how we do it in…but the very same thing. So, if you can alert learners that these things are interlinked. It's easy. It's easy. What we normally experience it's this knowledge gap, say, isn't you don't teach grade 10, 11, 12, there's teacher X teaching somewhere there. Then if that teacher has jumped some of the sections, to you it becomes a problem. Specifically, if you teach grade 12. That's where I got to realise that, oh, this learner, there's some concept missing, ja. So, it's…there are different dimensions involved. So, in most cases, more especially if you teach grade 12, you struggle to finish, let's say, a chapter. Because you want to first bridge the gap from the lower grades. And then by so doing time flies. So, it's a challenging situation.
Nomfundo	Okay. So then, you know some of the Physics concepts, for Physics and Chemistry, you know they are abstract, how do you help the learners make the link with their everyday life, like the real-world phenomenon, with the scientific context that we are talking about? How do you help them understand?
Mr Smith	The only thing to…
Nomfundo	To relate the content.
Mr Smith	To relate, as a teacher, you must find a very common, simple, everyday example. You first share that example with them. Then if they understand that one, then you bring that abstract concept. That's when they will relate. Oh!

	This in real life it's like this! Because like, if you talk in atomic point of view, it's like when you take this it's like imaginary. You cannot see it by the naked eye. So usually I used to joke, I say, no, you see Physics and the bible, they are always…it's very much abstract. If I can talk of heaven here, you'll have to think what type of space that is. So, you create a picture. Ja, so it's like some situations you have to create your own picture and then you relate it to what is happening around you. That's where you're going to grasp the concept. Otherwise, it would be a ghost. And once the learner does not understand that topic, ah! The attitude becomes somehow…
Nomfundo	So do you also use representations other than of course the Physical Sciences like the symbolic representation, like the equations and stuff like that, do you also maybe use pictures, videos, and stuff like that?
Mr Smith	Well, with videos we only use these video lessons, and we usually take them to the lab there and then they see what is happening…ja. If time allows. But at some stage you find that there's no time. The space is small there. The other teachers are also fighting to use the same.
Nomfundo	Ja. So, I see from your example of heaven and space like that, that you do use analogies in your teaching. How often maybe…is it more particular with Chemistry or with Physics?
Mr Smith	No, usually in this subject most of the concepts are not straightforward. And are very much abstract. So, you must be prepared every day to come with scenarios that will make them understand. Ja. Otherwise, you bring like examples that are like human related so they will see, oh, what is happening there.

Nomfundo	So, considering the fact that this place is like a rural area, so do you not find it difficult to find those examples, those scenarios that you can just help the students relate, or it's just okay?
Mr Smith	At some stage it will become difficult, but what…for someone to master you should be somebody who like to explore, read articles. Or as you share with other colleagues, they will bring different ideas. Then you can say, oh, this one is very nice example. If I present this one, then after that one I present this topic. Easy to understand. So, if you are just lazy and say, ah no, I just did that to the textbook, it becomes…for example, some of the textbooks, an example that they will state in there, it's very much urban. And there's a learner in the rural area who does not know what is…say even cars, maybe you talk of an airbag. You see, it's they will say what is an airbag. So, I must explain exactly to such an extent that the learner will know inside here there's an airbag, what it does when the car explodes, things like that…ja…so it becomes the lesson will be straightforward lesson. But if you bring those abstract examples…ja, sometimes you'll be speaking alone. You'll think that today, no, I've done a mouthful. They will say, you are playing. Come again. Do you understand? They will say no…or they will say yes, we understand. You present an activity, they say, no, we don't understand. So, hey! It's difficult to teach that subject especially in places like this. Then let's talk of Chemistry. You see with Chemistry, that's why if a learner passes Chemistry from a rural area, you must respect that learner. A learner who got level 7, even last year, who hasn't seen sulphuric acid, iodine, you know things like…it's always imaginary. You haven't seen the thing in real life, but you manage to pass. So, it's…I always tell people if a learner passed here with flying colours in this place, then you want to compare that learner with a someone who passed somewhere in South Africa, whereby we know that South Africa is Gauteng. So, you try to do comparison, ja, you see now, this side there was hard work. No access of this

	technological advancement. So, eish, it's tough, it's tough. But we are fine, you cannot give up. There's no way, you cannot give up. If somebody did it, why not us?
Nomfundo	Ja, I do definitely understand what you mean. So, there are also concepts like you see in…you see concepts like momentum. You know, when you go to a stadium, even if you are listening to a soccer match on the radio, you'll hear the commentator saying, they are gaining momentum, they are gaining momentum!
Mr Smith	Momentum, mm.
Nomfundo	So, but then the momentum that they are actually referring to in that, it's a different one from the one we talk about in Physics
Mr Smith	…Different…exactly.
Nomfundo	So how do you help learners understand such concepts? How do you help learners get through those concepts to understand that, no, the meaning is different even though the word is the same?
Mr Smith	If time allows, I think it's advisable if you say, you are approaching a topic, find those words that would be often used. And then compare with the general usage in the public space. In general people will use this word, but the meaning, when we are in this subject, it's different. For example, we talk of concentration. This learner doesn't concentrate.
Nomfundo	Yes, yes.

Mr Smith	But in Physics we don't talk of such, we are meaning the amount of…is it too much or is it less? Things like that. So, we must have those key words that we explain in advance. So that when you teach the learner must not confuse that word with the word he or she encountered in the English lesson. In geography or…because each subject has its own jargon. So, the learner must be vigilant with such words. And the only way to do that is when you introduce those words to the learner, that, oh, here when you use this word, when you say it's momentum, even the formula will tell you, if you are mathematically inclined, the formula will tell you, oh, here, you see you're multiplying a mass. It's a product. It's a product of mass and velocity. You are not talking of those momentum outside where they will say, haai! it's like you are gaining momentum it's like, ja, they are coming in full force! You see, things like that. And so, they must differentiate such problematic words.
Nomfundo	And you help them also to make that distinction.
Mr Smith	exactly, ja, ja.
Nomfundo	What about now if the concepts have got a similar meaning, like for example, the word resistance? Always when we speak of resistance, it always means the same thing. Except that in Physics, it's still resistance but it also involves a movement of either particle, you see. But the meaning is more or less the same. So how do you also help them? Do you also make them understand that…that they may be the same…the meaning is also the same, and stuff like that?
Mr Smith	Ja, it's like this, like normally when we teach, there's this code switching…ja, if you say the concept you are trying to explain, you run out of words in English. You switch to the vernacular. Then you bring simple examples…because if you say, let's say you are trying to push this thing, and

	it doesn't move. It means it is resisting to move. Then the learner will say, oh, okay, it's different from saying, okay, there's Julius Malema, when they president says this, he goes this way. He is resisting. So, you bring those scenarios. And they say, oh, here, resistance in our case involve directions…oh, vectors, oh, opposing each other. Ja, then they will say, oh, this is what they say.
Nomfundo	Okay. So…do you also teach natural sciences?
Mr Smith	They normally ask me to help them. But I'm not allocated to teach.
Nomfundo	Okay. So how familiar are you with the content…I mean, I'm asking in terms of how often do you integrate what the learners might have done in NS with what you're currently doing in Physical Sciences? Do you always go back to those things…so remember in NS you did this, and stuff like that?
Mr Smith	You see with these learners, I always tell them, that the basic knowledge in this subject you were taught in grade 9. They always say, no! I say everything was dished in grade 9. When you go to grade 10, we were sure that you have chosen this stream, you know you have the basics. So obvious you always go back. I said, this is…we did this in this grade, this is how it was done. Now we just put some spice…ja, gradually so.
Nomfundo	Okay. And then also maybe…do you also relate what they might have learnt, for example, if you are teaching organic Chemistry in grade 12, how often do you relate it to what maybe you might have done in an earlier lesson, or maybe to the topic of intermolecular forces, like maybe the same lesson or maybe across the different, you know, there's Physics and Chemistry, across, to also,

	you know, help them make that integration, linking the concepts from Chemistry to Physics?
Mr Smith	You mean like…? Give an example…
Nomfundo	…For example, in electric circuits, for example, we talk about the movement of charges, right? And then…but that's Physics. But the actual topic where we'll be talking about charges it's Chemistry. So, I'm just asking if maybe, do you also make those links between the two topics, if you see that this might be related to something they might have learnt in Chemistry and then you just bring it back to this topic.
Mr Smith	Ja, if that might happen then we can relate…remember in this lesson we did this but this side it's different, and you say, for example, we're talking charges, in Chemistry we'll be talking about of the positive ions, the negative ions, they are charges. So, but in electricity you'll be doing the flow of charge, there indicating those symbols of the battery that this is positive charge and will flow this direction, things like that. So, the learner will say, oh, there's a relationship in here. Though we are not talking about the very same concept, but it's linked.
Nomfundo	Okay. And then in terms of your learners, how do you engage them in your lessons…like maybe do you ask them questions and stuff like that? Or it's always through an activity and stuff like that…how do you engage learners?
Mr Smith	There are many strategies. At some stage, like when you come during weekends, you may prepare some questions. You first do one with them, and then the second one you group them, and then each group…then you may ask them, come and present. Then as she presents there, the other learners will see, oh, that mistake I did there (*interview disturbed*).

Nomfundo	You were still telling me about how you're engaging your learners.
Mr Smith	Ja, in a group of actions…you give them questions to do and then out of a group they will select a group leader, come and present a story. Then I will pick common mistakes there, as we try to elaborate and explain, that's how the whole class will see, oh, that should be done this way. And at some stage you deliberately do mistakes. You want to see them whether they can see that should not have been done. Then you manoeuvre in that way. Otherwise, you give them activities, they do it, you mark. Then the following day, if time allows, give solutions. You bring different questions from previous question papers, and there are a lot of questions, then you give them. Then that will tell you whether we're on the same path. If somebody is lacking, you allow them to ask questions. Gone are those days of you standing there, intimidate them to understand, even if they don't understand, they will say ja, we understand. Come exam time, dismally so, they fail. So, it's a problem. So, it's like, if you create that atmosphere of friendship with learners, allow them to ask questions, explain, smooth running of teaching and learning. But if you create a vicious cycle, it doesn't work. It doesn't work.
Nomfundo	Okay. So, when you are teaching Physical Sciences, what challenges are you experiencing as a Physical Sciences teacher?
Mr Smith	I think the only challenge…I don't know whether this government will come to our rescue. This thing we must teach with demonstrations. There must be demonstrations, not explaining, we must demonstrate…meaning like practicals. Ja, you must perform, and they will see, oh, this is what he's saying. If you mix this thing and this thing, the colour will be like this one. If you put this indicator, it will change to this colour. But if you don't have it, it's always theory, theory, theory. And sometimes it is discouraging. Ja, it's like a bible

	study. You’re talking of heaven; you’re talking of what-what. They haven’t seen those things. So, but if like there was a supply of those things, that was going to be a smooth subject.
Nomfundo	So, you don’t have resources?
Mr Smith	No, no.
Nomfundo	Do you even have a lab?
Mr Smith	That’s a ghost…who is going to create a lab, in which you won’t put anything! It’s like, for example, there are prescribed experiments. You have to go to a nearby school and borrow, if they have. If not, the only option, have a video lesson. There they will watch and say, okay, this is what they’ve done there. Then they will formulate their own…or copy those results that were presented. So go to a tertiary, then you are lost. You are lost, you don’t know how to assemble apparatus. It’s difficult. So, you may find learners who passed Physical Sciences from grade 12, they choose careers that are not physical related. They go to other fields because you know…first year they will go through, but second year they will realise, I’m lost. Because they are always performing practicals. Say you are doing Biochemistry, they are always in the lab, in the lab, and you don’t have the background. So, it’s a problem with these laboratories.
Nomfundo	So, the main issue is the lack of resources.
Mr Smith	Ja…in fact a science school should have a lab where sometimes learners will go there and perform. But…with us in rural areas, they struggle. No wonder our learners, they prefer to score high in paper one. Because it’s more of Maths

	than Chemistry. You see, in Chemistry you talk chemical equilibrium, always abstract. Ja, you must put that in her head, or his head, until they memorise, some will say memorise, you'll understand later. So, it's a problem
Nomfundo	…Eish! It's a problem.
Mr Smith	Ja, it's a problem.
Nomfundo	Other than lack of resources, what other challenges are you experiencing with regards to teaching this subject?
Mr Smith	Besides the lab…with the other learning and support material, I don't think it's a problem. The only issue could be the teacher chose a poor textbook, which is not well written. Because at some stage we had an argument, when they go for marking, the marking centre will have their own recommended science definitions or what-what. Then one will argue, no, my learner wrote this law from this textbook. And then this textbook passed all the standards, so why now we're saying this definition is skewed or lacks some…so that's where they now introduced the study guides
Nomfundo	…Oh, yes.
Mr Smith	Trying to solve that issue.
Nomfundo	So that at least there's some commonality

Mr Smith	…Ja, bringing the exam guideline with some definitions that the learner must strictly adhere to. If you bring your own, then you'll be penalised. So, things like that.
Nomfundo	So do you also go to the marking centre?
Mr Smith	I used to go but at some stage now I said, no, no longer. Others may apply.
Nomfundo	Okay. And then now with regards to this intervention that is going to be…that is scheduled to take place very soon, what are you hoping to benefit from it?
Mr Smith	The benefits will be to learn new approach in teaching. Because I may think the way I'm presenting is the perfect one, only to find that, no, it's good but you need some spice. So clearly that will boost me. The professionalism. That's where I'm going to learn new teaching approach. There are new assessment techniques, things like that. And what I usually recommend…I once talked to CI, she said, no, I'm coming, I said, you are welcome. So, she was talking to the principal. I said, no, but it's fine. Just come by my class. I want to see you presenting. Maybe if normally our learners when they see different face they'll have a different…they create their own atmosphere. When they have an unfamiliar face tend to…
Nomfundo	To scare them a bit.
Mr Smith	No, not scaring them. But attention-wise. They will attend to the person. But if the face is familiar, aah! This one, we know you, we know you. So, she used to do that and present a lesson. But sometimes you present a lesson, you don't know the learners, you are at level four, the learners are at level two. Then you

	are somewhere, they are somewhere. Then you think, ja, I've spoken a mouthful. Only to find that, no, you did nothing in fact. So, there are complex issues with learners. And what is worse, each year we have a different group of learners. So, when we say, why last year we performed better, this year, forgetting these learners their basic skills are different. Their knowledge gap. At one stage some were good, come the following year, hey! Very slow learners, very slow. In a…like a chapter needs four hours…and I spend two weeks. So that's the problem. You can relate this thing…if you check those model C schools, they don't have the so-called extra classes, weekends and what-what, Sundays camps. What's wrong with us? You come in the normal teaching hours, you go after school, you come weekends. So, you can see there's a problem. There's a problem. Sometimes I may ask, is it because this subject is offered in English? Some will say, haai, no! Some will say, it's just that we are not serious. So, I used to tell them that Physics, it's not for the lazy people. So, like in Maths, it's a daily bread.
Nomfundo	Are your Physical Sciences students doing pure Maths?
Mr Smith	The culture of this school, once you go for Physics, strictly, you take pure Maths. There's no way you can bring your Maths Literacy and then you say you…no, no. You'll be having problems.
Nomfundo	Ja, okay. So then do you have like language barriers, for example, I just heard you mentioned it?
Mr Smith	You see, like isn't that I sometimes teach Maths Literacy, and with Maths Literacy you don't just calculate. There's a story before. They would say this guy moves what-what. Then they ask a question, the learner will take a road to minority instead we're going to Zim. Then they say why? He or she will say,

	ah no, English! English is a problem. So, I wonder, why? Don't we have English teachers or English subjects in the school? We do. Why not understand this simple language. So, at some stage, you'll say I'll be creating politics here. Because you may wonder, what are the English teachers doing that make these learners not to understand this simple English or subject. So, it means you as a teacher in Physics you are going to teach English. You also have to introduce your Maths. Before you can talk your Physics.
Nomfundo	(laughs) Ja, ne, it's a lot. Thank you so much, Meneer, that will be all for today. Unless you've got maybe something else that maybe you'd like to share with me?
Mr Smith	No, this interview was nice.
Nomfundo	Thank you so much.
Mr Smith	I like engaging

Appendix H: Post-intervention Interview protocol

The aim of this interview schedule was to determine novice teachers' view of their teaching practices. This interview schedule was enacted in Mpumalanga after novice teachers participated in a professional development intervention.

Introductory questions:

- After participating in the intervention, what do you think about Physical Sciences as a subject you are teaching?
- After participating in the intervention, what do you enjoy the most about teaching Physical Sciences? Why?
- After participating in the intervention, what do you least enjoy about teaching Physical Sciences? Why?

Research Interview Questions

- Do you think the way you teach Physical Sciences has changed? Why or why not?
- After participating in the intervention, how do you teach scientific concepts?
- When teaching Physical Sciences, do you link scientific explanations with real-world phenomena? If yes, do you use any representations to make the link explicit?
- Do you include analogies in your lessons? Why or why not?
- Concepts such as momentum bear different meanings to different contexts, how do you help learners understand such concepts?
- Concepts such as resistance bear similar meaning to different contexts, how do you help learners understand such concepts?
- Are you familiar with what is taught in NS (the physics component)? How have you integrated that content with your current grade?
- After participating in the intervention, is there any change in how you link concepts when teaching Physical Sciences?

- After participating in the intervention, is there any change in how you engage learners in your lessons?
- After participating in the intervention, how often do you refer learners back to what they had learned earlier on during the lesson? Previous lesson? Previous Grade? Why?
- By participating in the intervention, what have you been able to achieve?
- Are there any challenges you are experiencing when teaching Physical Sciences?

That is all for today. Thank you so much for your time.

Appendix I: Post-intervention Interview transcript

Participant pseudonym: Mr Jones **Interview date: 25 October 2021** **Interviewer: Nomfundo Radebe** **Interview duration: 35:17**	
Nomfundo	Before we start, let me remind you that everything that you're sharing with me will remain confidential and your identity will be protected. You will remain anonymous in all my writing and everything that is being shared and done regarding this study.
Mr Jones	Okay
Nomfundo	Do you understand?
Mr Jones	Understood
Nomfundo	So, we are still sticking onto the consent form that you signed initially when we started.
Mr Jones	okay
Nomfundo	So now let's get started. Let's talk about your trial exams, how did it go? How did your learners perform?
Mr Jones	okay, there was an improvement with their results checking from June exam to trial examination. Although the improvement was not that satisfactory because it's still below 40. But there is an improvement. Also, there was a great improvement on paper one. Paper two, I cannot really say they improved, but they improved most in paper one,

	which somehow does not show the true reflection because when you combine them the marks will drop. But anyway, if there were to be separated, you would see that OK, paper one they have improved.
Nomfundo	Is there any specific topic in paper one that you think they've improved more on?
Mr Jones	Umm, actually after attending those classes with you, the one physical we attended at Bunny Khosa, some strategies we took, and we made use of them. They improved mostly on the topic electrodynamics. Most of them got total.
Nomfundo	oh. That's nice.
Mr Jones	yes, most of them got a total with those strategies. So, I can say that there were areas which we trained them and prepared them, even if we can get anything, but at least try this, this can give you 30. This can give you marks; you can pass using this. So yeah, that's all I can say that yeah paper one, they really improved mostly electrodynamics. Yeah.
Nomfundo	So have you been able to transfer the very same skills, the same strategies that you've gained from the workshops to different topics?
Mr Jones	yes, copy and paste
Nomfundo	I mean, how is it going? And maybe if there's something that you think maybe you are struggling with. Or maybe you are doing well on and these new topics that we didn't cover.
Mr Jones	Slightly I can say it is showing a sharp improvement. Because you can see we only managed to get time to do it and apply it on paper one that's why there was a great improvement in paper one. So, with paper two, we did not have much time to deal with paper two, but some

	topics which we touched from there, we try to implement those strategies, and I guess it is now that they are going to work.
Nomfundo	Interesting. OK, so. If the same Intervention was to be administered, is there any specific topics that you would have loved for the intervention to cover.
Mr Jones	A specific topic?
Nomfundo	mm
Mr Jones	No, not really, because the way they facilitated, you could tell that you can try to apply it on other topics just using their strategies. So, if I was to say like to be more specific that OK in this topic, I would love them to come and clarify to learners. You know our learners have that mentality of hearing new things from someone else, even if it's the same thing hearing a different voice somehow It helps, it draws the attention, they listen. You know, when you keep eating, pap and beans, when someone else cook the very same pap and beans, it feels different. So, I can say If maybe we were given the opportunity that our facilitators would come at least to our schools sometime just to do it themselves. Also, that would be beneficial.
Nomfundo	I see. If the very same intervention was to be administered next year, what would like to see us changing?
Mr Jones	Not really change par ser, but I would say we would start as soon as possible. Unlike this year we started late but would start somewhere around February and we start working with them, gaining those new strategies and scales. You know, working with someone with experience of more than 10 years and someone with an experience of two years or 3. There's a difference there, so the person with an experience of 10 years, during the year, will impose or impact like we make us gain the knowledge so that when we come back to our

	learners at least we can share new strategies. We can share that knowledge with our learners. We can see an improvement in our result. Like ourselves, our school has more than 50 learners to be attended. My suggestion would be to start early because we improved, we benefitted so it would be great to start early. We do it early so that by June our results have improved. Unlike now that we see the improvement now. You know another hand is needed for help.
Nomfundo	I remember the last time when we were having the first workshop, you mentioned that there were things that you were not comfortable with that were touched on. Can you please just elaborate more on that?
Mr Jones	OK, with regards to?
Nomfundo	we were having the first workshop, and I think it was electrochemistry and electrodynamics. So, you said that there were certain things that you were not comfortable with, probably on one of those topics, and then now that they were teaching them showing you the strategies on how to cope with them and feeling a bit more comfortable.
Mr Jones	yeah
Nomfundo	so, I would like you to just collaborate more on that.
Mr Jones	There’s a part of electrochemistry. Actually, with also with Electrodynamics. There are certain things which I was not quite sure of and some things. Even if you can try to search from your textbook or Internet, you might find that explanation as saying that experience count. So, someone with experience has encountered these challenges not once or two times. Later they found a solution. Then we got to be given the opportunity to receive the new strategies. That's why I'm saying in electrodynamics most of my learners got a total because we

	copied what we got from the intervention or from the workshop we attended there at Bunny Khosa.
Nomfundo	On the first workshop, you received materials. Have you been able to use it?
Mr Jones	yeah, and very profitable.
Nomfundo	Explain to me how.
Mr Jones	You know what I did, I tried to make copies of everything that we received. Most of the things that I needed to give them, learners. And then I gave them. They use them as their notes. The questions that were there, we wrote them as activities. I think it really helped because when you check their performance, you can tell that these learners were sure of what they were writing. You know, with electrodynamics, for example, I used mostly the material. It's not really easy to understand, but it's easy to answer. You can answer and get a total without understanding, but this time around we were understanding. I remember the pamphlet that we were given, I made copies for each, and every learner and it was easy for me to teach, teaching them knowing what I'm teaching and having strategies to teach them. Like you even feel more comfortable to explain whatever that you are explaining. Unlike having to explain something that you don't even know, we are just explaining because they said this is done this way. Yeah, so those pamphlets were very useful.
Nomfundo	What about the practical's equipment, The micro kits?
Mr Jones	OK, that one we did not have the opportunity to run those practicals. But I took 3 learners, we tried with 3 learners and unfortunately it didn't work out because I think I needed a thermometer or what? It was missing, so that's why we couldn't finish off our stuff. But we did try, we did try, because I ended up trying something else, I don't know

	whether it's thermometer or what. It’s even there, trying actually. So yeah, I think it's good to have something like that, so that they know how we connect this, and this is what we see. Even when you answer in theory, you know what they expect from you. Unlike having to answer something that you have never seen. You know, it's easy to remember something that you've seen, unlike something that you’ve heard. Yeah so, I think next time we'll have more time and then more learners will be exposed to also trying and doing the practicals and see what's happening.
Nomfundo	You just mentioned now how the material has helped you to teach some of these things. Have you noticed any knowledge gaps in your learners?
Mr Jones	Yes, you know these learners they rely only on what you give them. You give them a textbook; they don't do anything with it. You give them notes, they rely on your notes. So, the more you provide them with material, is the more they rely on the material and the same material is in the textbook. So, it helps them to study. It helps them to be prepared, to be ready. Like now. I've given them a task to write because I know I am preparing them for the final examination. So, if you don't do anything you keep teaching, you keep revising with them, they also revise with you. But then they don't know the content. They don't know how to answer, but at least if you give them an opportunity and say, sit down, write this. Tomorrow when they write again, it feels like it's usual to them. It's not something that they see for first time. It also builds their confidence, like I know this. By providing every needed material, it boosts your confidence. You can say you know what, I have everything that I need for this, so yeah.
Nomfundo	In terms of the knowledge gaps that they are having, you’ll notice that most of the content, for example if we speak of Newtons laws, they

	are in Grade 10, they are not in Grade 11, they are in Grade 12. In fact, most of the content, if you remember when we were doing the breakdown of that structure of what the question Papers looks like. You will remember that we said most of the content that is in grade 12 is the content that is being taught in Grade 10.
Mr Jones	yes
Nomfundo	So how are you working around that considering that we've had the workshops and now you understand what is happening in terms of the Question Paper and everything?
Mr Jones	Yeah, we normally do what we called a revision. Normally when you open the textbook before they introduce a new topic, they take you back to Grade 10 or Grade 11. So, what we do is, we do a summary of revision. Let's say we are going to Newtons law; we revise Newtons law using the basic structure from grade 10. So that they remember that this is what we are doing now, as if they're starting a new thing. So, after revising when you teach them, it becomes easier for them to understand. We don't keep the notes of saying now they've done it in grade 10, now we are continuing. No, we do try to close that gap by doing some part of revision. Mostly more on things which are more relevant to what they will be doing.
Nomfundo	OK, and then now if you remember some of the intervention workshops were online and some of them were physical. I think about four of them were online, two were physical. How did that mode work for you? Which one works best if I can ask?
Mr Jones	Yeah, you know the online…It does help but I think we have more challenges than when we are doing it physical. With physical, the only challenge is that even if you want to attend with your learners, you can't because the space will be limited. But online I can attend with

	my learners. I can use a projector; we sit down, and they also listen at the same time. So, the only challenge with online, you know online we'll be experiencing maybe network problem. You know. I remember there was one which I couldn't even log in because of network. I remember I was not around; I was on a workshop and at the place my network was not supported, I am using Telkom. So, if I'll be having a challenge of network, it means I won't be able to attend, but when it comes to physical, with or without network, with or without electricity, you see the person and they will be like yeah. They both work, depending on the challenges that we face when we are attending them because with the physical, I cannot attend with my learners. But for me to benefit the learners, I need the virtual one but at the same time I must be in a place where I am covered by signals otherwise I can't. Like I remember we were doing, was it rate of reaction? I don't know. That one was very useful. I was able to connect here and then they were listening.
Nomfundo	oh, they were there?
Mr Jones	Yeah, they filled this place.
Nomfundo	Nice
Mr Jones	They were watching here and if we are busy asking questions, they were listening. I was asking questions as a learner, they were also listening and benefiting, taking notes.
Nomfundo	Interesting. It must have worked well for you because that question was done on a Friday, and they were due to write paper two on Monday.
Mr Jones	Yeah, that one was very useful, you know. Actually, I think that's how we should work. That's how we should target when we are writing paper one, few days before we target the areas in paper one where we

	can get marks. Like they are topics, which we normally look down on them and say no, these ones are difficult, yet they can be broken down and then we can take few months. For example, acids and bases, acid and base questions, they are not really difficult. There is only one question, the 7 marks, 8 marks, 9 marks question. And on that question, you can get 3marks so learners must know that even if you can't get the whole 9 marks or 7 marks, there is a question that you can get here by writing this formula and substituting you get 3 marks. So, the other questions of proton donor, Arrhenius what, those ones are very simple.
Nomfundo	I get what you mean. Were there any challenges that you were experiencing when it came to attending the workshop other than the Internet access, any specific challenges that you are experiencing?
Mr Jones	Ah, I cannot really say challenge, not really. No, there were no challenges, except that the last workshop where we had to attend at School A, I was supposed to go somewhere.
Nomfundo	Personal commitments
Mr Jones	yeah, but I cannot say it’s a challenge. Because these schools are just nearby.
Nomfundo	And then what about with regards to the content that was delivered, did you experience any challenge? Maybe that no, this is not how we do it or something like that. Any mismatches that you might have noticed from what we're doing with regards to what you're expected to be doing in your profession?
Mr Jones	No, I don’t normally go with that mentality when I am attending something. I am open to learn new things. Yeah, like I don't limit myself when I see something which is new and I don't even understand, I will just check it, like consultations, maybe they will

	explain it properly. And if it's something that I can use, I use it, but if I feel like no this is not good for me, I'll just continue with what I'm doing. So, but from what I've observed, no there wasn't. Actually, it was something to gain.
Nomfundo	With regards to Issues of language that you would normally find that learners are… remember last time we spoke about language of Science being a language itself. Do you remember So, is there anything that you picked up from the workshops that will help you help your learners regarding that particular aspect of them understanding some of the concepts that we're using that their meaning is the same, in some of them the meaning is different although the concept is still the same. Something like that.
Mr Jones	Yeah, with that you know it's still a bit difficult to be break down because you still need to deal with the mind of a learner. You still need to try and convince them. You still need to try and make them understand that, OK, these, like for example when you are dealing with chemistry. Chemistry has a lot of…we will normally make examples of chemical reactions with something that is tangible, something that we see. And yet with chemistry, we are dealing with chemicals and mostly it's something that you can't even see, can't even touch. You can only see using those material. so, we try and also at the time try to make them understand that you know what, this is not what we are saying, this is a reaction, we are just making it for you to understand. So, in terms of language and science, it's still a bit of a challenge because you need to find examples which are more practical, more realistic, unlike...If we can look at our school, we don't even have a lab. So, you can't even refer them that you remember the practical we did, you saw that after adding H_2SO_4, what happened to the reaction? So, you need to take H_2SO_4 as something

	else. You make it maybe yeast, you know. They know yeast, they are used to it. You must make them understand that oh, H_2SO_4 is more like an acid or it's more like yeast, it’s a catalyst. And when you add it, this will happen. So yeah, we do try to make them understand it.
Nomfundo	in terms of the science concepts, did the workshop help you break down some of the difficult concepts that you really thought that these were some of their most difficult concepts that learners would normally find, for example, the strategies that they were showing you. I mean, how to break them down basically?
Mr Jones	Yeah, like as I highlighted the rates of reaction and also the electrodynamics with electrochemistry. Nor necessarily electrochemistry, but rates of reaction. They normally don't answer that question. They think it's difficult. And then after that workshop, they thought they were just skipping a question which we can answer without even understanding. You know you need to know the definition; you need to know the formula. You know that you have 5 marks for that. And then you need to try and analyse what is happening to the reaction. If you can check, physics, is very simple to deal with. It's only three reactions that they keep interchanging. So, like now, they're busy answering the questions. So yeah.
Nomfundo	I find it very interesting that your learners actually found the workshop very interesting for them that I mean, we don't have to skip this. I mean, yeah, it's just one of those things.
Mr Jones	Yeah, you can take longer. Here there are marks you can take. Even if they don't understand. It’s a definition, it’s a formula, 5 marks you take.
Nomfundo	Yeah. At some point I'm quite sure you also saw there was a WhatsApp message that one of the teachers was talking about learners

	being demotivated, not interested and stuff. Did the workshop help you to help your learners be motivated on the topic itself?
Mr Jones	Yeah, you know with that one, there are many instances where I found people having to complain with something in life, they normal experience it themselves. Why am I seeing with this? you know if you yourself are not demotivated, you cannot allow someone else to be demotivated. Even if you see that this person is demotivating, you try to uplift them. And you try to motivate them so it's not easy for you to find a way to motivate someone, yet you're also demotivated with the same thing. If the teacher or I am motivated, I'm always motivated to go in class and teach. I wouldn't take pride when they see these learners fail. When they fail, I need to sit down with them. I need to talk to them. I need to change their mentality, their way, their attitude. I try other means; how can I talk to them? How can I make them understand? You know, it's starts here. Yeah, so if they understand that you know you can also pass this. Start with the teacher. So, the workshop did build our confidence, so when you go to class you know what to do. Also, the learners will know what to ask.
Nomfundo	I see what you mean. And then in terms of Support, was your management here at school aware that you were attending an intervention workshop?
Mr Jones	Yes, they were aware, and they were very supportive in that. Some workshops I would receive notifications that you will be attending and also the principal sent that you will be attending this. I remember there was a workshop which I missed, I had to write a letter to explain why I did not attend and also the principal ha to write a letter to support. They were very supportive and everything we do here. In terms of curriculum, I have no complains.

Nomfundo	Is there anything more that you probably would like them to do in supporting you? For example, the online workshops were starting at 3 o'clock until 5, maybe say you needed to end your classes earlier, something like that. Is there anything additional that maybe if the same workshop was to be administered next year, you would require from them so that the workshop experience would be much beneficial for you?
Mr Jones	So that I can be given more time here?
Nomfundo	Yes
Mr Jones	Not really because here we don't work under pressure. You know the workshops are occasional, it's not always. So, if I am to attend the workshop and I see that not today I need to be at the workshop I will just, maybe before that time I can prepare myself. I am allowed to do that, so I don't see any need to make new arrangements.
Nomfundo	You have attended workshops from the department, isn't it? Is there anything that you noted that was different from this workshop compared to the one that you normally attend with the development? And maybe any note of improvement?
Mr Jones	Actually, they were quite similar. But the reaction with the one we attended with you is a bit different because its provincial. In terms of workshops where we have to come and sit down and discuss, maybe the paper or discuss some of the topics, we would also have experts in those topics coming to facilitate. But yours was much more improved than the way we do things. Isn't that this is home. So, when you are attending anything at home, you just do things at home. So, it's more like when I have something to attend at home like this, I cannot prepare something extraordinary if we were to talk, we just sit down and talk, it done we are going. So, if someone is being invited,

	we go an extra mile. So, I think it's the same, the difference is that the other one is from the provincial level and the others we are doing them from the cluster level. That could be the difference.
Nomfundo	Is there anything else maybe that you would like to share with me regarding your teaching practice so far after the intervention as well as the intervention itself?
Mr Jones	Yeah. All I can say is to say that we appreciate your time and sacrifices. I know you would have gone to other schools, but you decided to pick our circuit and came to work with it. We also benefited and we really appreciate it. We don't take that lightly. I don't have any complaints because there was nothing to complain about. Instead, we were gaining from everything. So yeah. I think that's all I can say.
Nomfundo	Now I'm speaking to you in terms of your qualification. How has the experience been for you coming from a B.Sc. background, how has it been? I mean you can also see other B.Ed. teachers, qualified teachers, and here you are from a B.Sc. background, how has it been?
Mr Jones	In relation to the workshops?
Nomfundo	Yes
Mr Jones	OK, I don't know much about the B.Ed. group. With us B.Sc., my B.Sc. is not much more of practicals where you have to do practicals and use chemicals. I do B.Sc. in pure maths. So having to intervene like you did, like attend the intervention, I think it was more beneficial to me because I was exposed to most of the things which I was not even aware of. It did help me because I'm just branching from something like jumping not knowing what is happening in between. So, the workshop was able to break, not all but most of the important

	stuff which I was not even sure of, and then at least they tried to make me to be knowledgeable. So yeah, it was good experience.
Nomfundo	Can we safely say that we will see you in the teaching profession for the next 10 years to come? Are we going to lose you to B.Sc.?
Mr Jones	No. The chances are 75%
Nomfundo	That you will stay here.
Mr Jones	Yes
Nomfundo	Thank you so much, Sir and thank you so much for taking the time to do this interview.
Mr Jones	You are welcome.
Nomfundo	Thank you very much.

Appendix J: Lesson observation Schedule (pre and post intervention)

Participant pseudonym:
Observation date:
Observed by:
Topic taught:
Lesson duration:

<u>Investigating the effectiveness of a blended professional development intervention in improving the teaching of Physical Sciences: A study of novice teachers in South African rural schools</u>

The aim of this observation is to determine how novice teachers are teaching Physical Sciences before and after participating in a blended professional development intervention. This observation schedule was enacted before and after the novice Physical Sciences teachers in Mpumalanga province participate in a blended professional development intervention.

Time	What is the teacher doing (gestures/behaviour)	Are there any scientific knowledge/explanations/	Are there any everyday knowledge/explanations/	Are there any representations

		phenomenon being used/referred to by the teacher in the lesson? If any, how were they used?	phenomenon being used/referred to by the teacher in the lesson? If any, how were they used?	(visuals/objects/symbols) that are being used by the teacher? If any, how/why were they used?
5 Min				
10 Min				
15 Min				
20 Min				
25 Min				
30 Min				
35 Min				
40 Min				
45 Min				

APPENDIX **K: O**BSERVATION **T**RANSCRIPT **(**PRE**-**INTERVENTION**)**

Participant pseudonym: Mr Brown **Observation date: 23 June 2021** **Observed by: Nomfundo Radebe** **Topic taught: Factors affecting the Rate of Reactions** **Lesson duration: 1:34:16**	
Mr Brown	Good morning
Learners	Morning
Mr Brown	How are you?
Learners	We are well
Mr Brown	I am also well. Today we have a guest, ne? I will let her introduce herself. *(Giving handouts).* What I have just given you is a copy of the exam guideline. I need you to paste it on your exercises, on the classwork side. (pause) So today we are going to do the (writes) rate and extent of reaction. Rate and extent of reaction. Before we do that, we have to revise some terminologies
Learners	Mm
Mr Brown	Like reactants. What are reactants? If one still remembers, what are reactants? Okay we have what, reactants (Writes: reactants) that are sometimes called reagents, and we have (writes) products. For every chemical reaction, there are reactants and products, right?
Learners	Mm

Mr Brown	Reactants are sometimes called reagents. So, they are substances that combine to form products, right?
Learners	Mm
Mr Brown	Products are what is formed when reactants combine, right?
Learners	Mm
Mr Brown	For example, if I have an (Writes: A plus B = C) equation of A plus B producing C. For a reaction we know we don't put an equal sign, we put an error which stands for yield or produce, right??
Learners	Mm
Mr Brown	Alright, for a reactant to combine we have a theory that we use called collision theory. Most of you learnt it in Grade 11, the collision theory. Let's make an example we are familiar with for maybe elements and products. We have element carbon, you all know carbon, right?
Learners	Mm
Mr Brown	Carbon reacts with oxygen, and we know that oxygen is a diatomic molecule, right?
Learners	Mm
Mr Brown	If carbon reacts with oxygen, what do we get as our result if these two combines?
Learners	Carbon dioxide
Mr Brown	We get carbon dioxide with symbol CO_2, right??
Learners	Mm

Mr Brown	In a chemical reaction, it will not always be a case that you will get reactant A and B reacting to form C, sometimes you will get reactions where two reactants combine to form more than one product, right?
Learners	Mm
Mr Brown	Do you understand?
Learners	Mm
Mr Brown	For example, if you have magnesium, Mg, reacting with sulphuric acid which is H_2SO_4. What do you get? Magnesium reacts with SO4 you get (writes) Mg plus SO_4 plus H_2 which is a gas. In other cases, when two reactants combine, they form one or more products. Then now, moving into collision theory. The collision theory says, this is just a revision, right?
Learners	Mm
Mr Brown	The collision theory states that for a reaction to occur or for A and B to combine in order to form C, these two reactants must collide. Collide means to bump onto one another. Collide in Xitsonga means what?
Learners	*Ku chayisana*
Mr Brown	*Ku chayisana*, right?
Learners	Mm
Mr Brown	So, for a reaction to occur, A and B must bump onto one another in order to form C, right?
Learners	Mm
Mr Brown	And the way they collide, they must collide at the correct orientation. Do you understand

Learners	Mm
Mr Brown	And if reactants collide at a correct orientation, we say they have effective collision. So, for a reaction to occur between atoms, ions, and molecules collision theory states that for a reaction to occur (writing on the board) ...Ions, we know ions. Do we know ions?
Learners	Mm
Mr Brown	An example of an ion is H^+ ne
Learners	Mm
Mr Brown	Then for O^{2-}. This one is an ion for oxygen and this one is an ion for hydrogen, do you still remember?
Learners	Mm
Mr Brown	Alright. Then for a reaction to occur between atoms and ions, molecules must collide. That is simple collision theory. And they say when the collisions occur, they give molecules energy. Or collisions give the necessary energy for these reactants to bond together, right?
Learners	Mm
Mr Brown	As a result (*pause*) They have correct orientation to form products. Now if we know what reactants and products are and how products are formed when reactants combine, we can now define the rate of reaction or reaction rate. We talk about rate in physics as well as in Chemistry. The term rate is the same, it means per unit time, or it means we divide with time. According to the exam guideline that I said you must paste; they define the rate of reaction as the change in concentration of reactants or product per unit time. Whenever you are asked for a definition, you do not go to Google. You go to your exam guideline and define the rate of reaction as the change in concentration

	of reactants or products per unit time. By that statement, mathematically they mean the rate is equal to the change in concentration of products per unit time. Per unit time we know that we divide, right?
Learners	Mm
Mr Brown	Then, using symbols, rate is delta C where C is a symbol for concentration. The formula to calculate concentration is C IS Equal to n over v. Do you remember it?
Learners	Mm
Mr Brown	Then divide by change in time. If you say you remember that concentration is denoted by letter C, it means you know the units for C. What are the units for C, concentration?
Learners	Mol per decimetre
Mr Brown	Its mol per decimetre cube divide by...What is the SI unit for time?
Learners	Second
Mr Brown	Its seconds, right?
Learners	Mm
Mr Brown	Which is small letter s, right? Then it means the unit for rate is mol per decimetre cube per second, right?
Learners	Mm
Mr Brown	Remember, from definition they are saying to you the rate of reaction is the change in concentration of reactants or products per unit time, right?
Learners	Mm

Mr Brown	Now remember this formula only accommodates the products, right?
Learners	Mm
Mr Brown	It means you can change here to say that it is the change in concentration of reactants. Isn't?
Learners	Mm
Mr Brown	Whenever you are given the concentration of reactants, the formula will be change in concentration of reactants divide by change in time which is still change in C all over change in t, which is mol per decimetre cube per second, the units, right?
Learners	Mm
Mr Brown	This is not only the case for the rate of reaction, but you can also go into an exam room, and they tell you that or give you a mass and time and say so many reactants are used up in maybe 2 seconds. They say 10 grams are used up in 2 seconds. You can still have the rate by converting the mass to concentration. From concentration you get the rate. How do you get the concentration if we have the mass? You first calculate the number of moles. You find the number of moles by n is equal to small letter m divide by the molar mass, right?
Learners	Mm
Mr Brown	Then we use formular C is equal to n over v. Number of moles is given by m over M then C is n over V where V is volume, right?
Learners	Mm
Mr Brown	So, there will be many cases where they can ask you about the rate of reaction
Learners	Mm

Mr Brown	So, there will be many cases where they can ask you about the rate of reaction. But every time whenever this question is asked in a question paper, they will tell you the units before asking, right?
Learners	Mm
Mr Brown	If ever maybe they want the units in mol per second you know your formula is. Mol per second is mol divide by a second isn't?
Learners	Mm
Mr Brown	These are units, they are units for what? They are units for the number of moles, right?
Learners	Mm
Mr Brown	The number of moles is denoted by letter n, right?
Learners	Mm
Mr Brown	Then second is denoted by time whereby you have rate equal to change in number of moles divide by change in time isn't?
Learners	Mm
Mr Brown	Every time they will specify which unit they want the rate to be in. Do you understand?
Learners	Yes
Mr Brown	Are we together?
Learners	Yes
Mr Brown	Any questions? Any questions? You can also have rate of reaction in grams per second which is mass divided by time isn't?
Learners	Mm

Mr Brown	An example for a rate of reaction…this example says the following reaction takes place. We have (writes: 4Li + O2 = Li2O) four of lithium, we have O_2 and two Li_2O, lithium oxide. After two minutes, four grams of lithium has been used up. It means after 2 minutes 4 grams of lithium is finished. Calculate the rate of reaction in moles per second. You see they gave you the units that they want their rate in which form. There are no moles given in that reaction, right?
Learners	Mm
Mr Brown	It is your duty to find the number of moles before calculating the rate. Do you understand?
Learners	Mm
Mr Brown	Alright, then now, in that reaction, which ones are reactants? Which ones are reactants in that reaction? It's these ones, isn't?
Learners	Mm
Mr Brown	It means the products, what is formed, are these ones, isn't?
Learners	Mm
Mr Brown	Let us try to find the rate here. You must first convert these 4 grams into number of moles, right? How do you find the number of moles? Number of moles is equal to mass divide by molar mass, isn't?
Learners	Mm
Mr Brown	You write the formula before anything isn't?
Learners	Mm
Mr Brown	There is a mark for that. Alright, then its substitution. How do you find the molar mass? You find the molar mass by looking at the periodic table isn't?

Learners	Mm
Mr Brown	The molar mass in the periodic table is the mass number, right? Then this one, the mass is 4 grams isn't
Learners	Mm
Mr Brown	Divide by molar mass is what? The molar mass of lithium. We are talking about lithium. You don't have periodic tables? Who has a periodic table in this class? What is the molar mass or the mass number of lithium? Its 7 grams per mole, isn't?
Learners	Mm
Mr Brown	Then here, 4 divide by 7, you use your calculator. What do you get?
Learners	0,57
Mr Brown	Zero comma?
Learner	57
Learners	57 what? Mole. How did we arrive to mole? We don't know the units; we know that the unit for molar mass is gram per mole. This gram divides this gram, isn't?
Learners	Mm
Mr Brown	This per mole is the denominator, isn't?
Learners	Mm
Mr Brown	Laws of exponents, if we take the exponent to the numerator, negative times negative, it will become positive one and you get 0.57 mol, right?
Learners	Mm

Mr Brown	Now we have the number of moles, and we have the time taken isn't?
Learners	Mm
Mr Brown	If you see the time, it's given in minutes. Do we use minutes in rates?
Learners	No
Mr Brown	We don't. What do we use Learner A? Do we use minutes, seconds, or hours, which one do we use?
Learner	We use seconds?
Mr Brown	We use seconds, right?
Learners	Mm
Mr Brown	Therefore, we need to convert 2 minutes into seconds. How many seconds are in a minute
Learners	60
Mr Brown	60 seconds. The time will be 2 minutes times 60 seconds, isn't?
Learners	Mm
Mr Brown	What do you get? 120 seconds, right?
Learners	Mm
Mr Brown	We have the number of moles and time. Remember they said they want the rate in mol per second. If ever they said they want the rate in per minute, we would leave the time as it is in minutes isn't?
Learners	Mm
Mr Brown	It's equal to (writes) change in number of moles divide by change in time. Here we have delta n over delta t, isn't?
Learners	Mm

Mr Brown	Which is 0,57, this is substitution, 0.57 divide by 120 seconds, right?
Learners	Mm
Mr Brown	What do you get?
Learners	4.75
Mr Brown	4,75 times 10 exponent negative 3. And we write the unit as mol per second. Will you not be able to do this? Learner B, will you not be able to do this?
Learner	Mm-m
Mr Brown	You will, right? Learner C is that difficult?
Learner	No.
Mr Brown	It's not difficult, right?
Learners	Mm
Mr Brown	Okay let's move on. Now let's talk about rate and extent of reaction. There are factors that increases this rate of reaction. There are factors that decreases the rate and extent of reaction, right?
Learners	Mm
Mr Brown	These factors are six, do you understand?
Learners	Yes
Mr Brown	We will discuss all these six factors today in relation to the rate of reaction. You are nervous you are writing… Okay, we have factors affecting rate of reaction.
Learner	Sir
Mr Brown	Yes

Learner	Can I ask, when we are looking for Molar mass of Lithium, do we still consider our equation.
Mr Brown	When we are looking for the molar mass, molar mass did what?
Learner	Yes, that of Lithium. Are we not using our equation?
Mr Brown	The molar mass, how do we get the molar mass guys?
Learner	I know that consider the Periodic table.
Mr Brown	From periodic table, or maybe you mean if we were looking for a molar mass for this one. I don't understand you.
Learner and Mr Brown	(Inaudible)
Mr Brown	Okay, can we move on?
Learners	Yes
Mr Brown	Factors affecting the rate of reaction. They can either increase or decrease the rate of reaction. Each of these factors are important because they will be asked at the end of the year. They will ask you to explain them using the collision theory, stating why any one of these factors will increase the rate of reaction. I gave another set of paper which has four blocks. The factors will be examined, the first one is nature of reactants. By nature of reactant, we mostly talk about the state of reactants. The states are phases of matter. States of matter include liquids, gases, and solids. Here in grade 12, we also have solutions. We mostly talk about the state at which the reactants react. Maybe we have a liquid, a gas and a solid and a solution. Remember when writing a chemical equation, you need to indicate that maybe for hydrogen it is in which state. So, for a liquid, the symbol is small

	letter L, for a gas is g and solid its s. Then for solution is what? Its aqs, for aqueous isn't?
Learners	Mm
Mr Brown	Alright. In the nature of reactants, this is what we basically talk about. Okay, for example, how does this one affect the rate of reaction? If ever maybe a liquid and a gas react to form a product, a liquid plus a gas they form products. At the end of the day, a product will be formed if they collide at the correct orientation and effective collision will occur, products will be formed. Then you say a gas and a solid, a solid plus a gas they form products. In this case, it is easy for a gas to dissolve in a liquid, isn't?
Learners	Mm
Mr Brown	Do you understand? You don't understand?
Learners	Mm
Mr Brown	It is easy for a gas to dissolve in a liquid. But it is difficult to a gas to dissolve in a solid. If we look at it generally, for a gas to dissolve or combine with a solid its difficult than with a liquid and a gas. Then it means for the first one, the rate of reaction will be higher. More products will be formed in a less time. It will have a greater rate of reaction. Then for this one, we will have products forming at the same time as this one. Do you understand? You don't understand, right?
Learners	Mm
Mr Brown	Let me start afresh. Let us take a gas, no, let's take a liquid with L reacts with a solution. A solution is a state isn't?
Learners	Mm

Mr Brown	It forms products. You take pure water and lemon juice. Lemon juice is a solution, it has ions, we react them together. Then now we take a solid and we react it with a solution to form products. We said our liquid is water and our solution is lemon juice. You know that it's in aqueous form since it's a solution. Then we take a brick, it's a solid isn't? You don't know a brick? (Laugh). Let's take your calculator, it's a solid isn't?
Learners	Mm
Mr Brown	You react it with the same lemon juice ne.
Learners	Mm
Mr Brown	If this calculator really reacts with lemon juice to form products, provided collisions occur at correct orientation such that they are effective collisions, the calculator will react with lemon juice. It's just a scenario, we all know it's not true, right?
Learners	Mm
Mr Brown	It just an example. Then if you use your mind, in which equation there, the first or the second one where products will be formed quickly? The first one isn't?
Learners	Mm
Mr Brown	Because it's easy for a liquid to react with a solution rather than a solid with a solution. Then the nature of reactants affects the rate of reaction. Do you understand?
Learners	Mm
Mr Brown	We will come back to this one at a later stage, right?
Learners	Mm

Mr Brown	The second factor is temperature. You want to make tea. To make tea, you heat up water. Why are you heating up the water? If you are heating up the water, you are increasing the temperature. Increasing the temperature allows the sugar that you have put in to dissolve quickly. Otherwise, if it was cold water from the fridge, it can take 25 minutes for the tea to be ready. Tea doesn't have to be hot. We now have iced tea; do you know it?
Learners	Mm
Mr Brown	For temperature we speak of how cold or warm or hot a reaction is. So, an increase in temperature increases the rate of reaction. A decrease in reaction decreases the rate of reaction. Another factor is concentration. This one is number one, this is two, now this is number three. The factor is concentration. Suppose you wanted to wash your jersey. This is water and this is water, right?
Learners	Mm
Mr Brown	You take sunlight, OMO or SURF. You take one scoop of surf, and you pour it here and then in the other container, you take and pour two scoops of surf, you want to wash your jersey. Which solution there will be able to remove dirt faster, the one with less soap or more soap?
Learners	The one with more soap.
Mr Brown	Where there is lot of soap, right?
Learners	Mm
Mr Brown	If ever you put more soap in this container, you are increasing the concentration. If you put less soap, its less concentration. Do you understand?

Learners	Mm
Mr Brown	Where there is higher concentration, you will quickly remove your dirt, meaning the rate of reaction is faster when the concentration is greater than when concentration is less. Basically, an increase in concentration of reaction increases rate of reaction. Decreasing the concentration of rates of reactions decreases the rate of reactions. That's not difficult to understand, right? …are you still, okay?
Learners	Mm
Mr Brown	Any questions? None, right? This was the third factor. The next one is surface area. By surface area we are talking about the size. Do you see these chalks, these two? Or let me say, this is the chalk ne, can we all see this chalk? We are talking about the size. If I break this chalk into pieces, I am increasing the surface area, right?
Learners	Mm
Mr Brown	By increasing the surface area, I am decreasing the size of this chalk. This is still the same mass, but now it has a larger surface area. By increasing the surface area of reactants, we are increasing the surface area of products. (draws) This was my chalk, the small pieces that I broke. I can still increase the surface area of the chalks I broke, by crashing them so that they can be powder. The size of particles in a powder are very small. Whenever you are increasing surface area, isn't that the chalks are here in this container? If I increase the surface area, they will end up reaching here. There will be a lot of pieces inside, which gives the reaction more chances to collide. If ever we are five in this class, we can collide. If ever we can be 100 in this classroom, we have more chances of hitting one another and by those collisions, we give the reactants more chances of effective collisions and forming products. So, increasing the surface area increases the

	rate of reaction. Decreasing the surface area decreases the rate of reaction. That's why you will hear old people saying the tablet Grandpa is not effective compared to the powder one. What do you say?
Learners	It's the same
Mr Brown	It's the same? Okay, then we have a catalyst. In agriculture, there is catalyst, is it there? Or in Life Sciences?
Learners	Mm
Mr Brown	Oh, in Life Sciences, there is a catalyst. How do you define a catalyst in Life Sciences?
Learner	Something or a substance that speeds up a chemical reaction
Mr Brown	It's something or a substance that speeds up a chemical reaction, isn't? Do you all understand this that a catalyst speeds up a chemical reaction from Life Sciences? Here in Physics, a catalyst is a substance that increases the rate of chemical reaction without itself undergoing permanent change. In the exam guideline that I gave you, it's there. The definition is there. They say define a catalyst as a substance that increases the rate of chemical reaction without itself undergoing a permanent change. It simply means that it speeds up the process or it speeds up the chemical reaction without taking part. An example of a catalyst is whenever there's a wedding, they slaughter a cow on Saturday around 5 in the morning. Around 7 the meat is ready. Will the meat be ready by 7? Will it be well cooked?
Learners	No
Mr Brown	What our parent does it is adding cooking soda. The cooking soda is not part of the meat, but it makes the meat to be ready quicker. Take the cooking soda as a catalyst ne. Isn't that when you are cooking,

	you just put the meat plus water. This is what you do when you boil it. But if they boil it this way, it will be ready around 1. Because our parents are scientists and educated, they put a cooking soda, so that if they start cooking around 5, by around 5H30 they are done. We eat and deal with the consequences. (Learners laugh) You know there are consequences for eating that meat?
Learners	Yes
Mr Brown	It is better you know. Alright, you must know the definition of a catalyst. It is important. The last one is pressure. The last one is pressure. Pressure, whenever you see a chemical equation with maybe reactants or products where there are gases, consider the pressure and take out concentration. Pressure only applies on a chemical reaction in a gaseous state. It only applies in gasses. Then the concentration applies for everything except gases ne. Here, no gases. Pressure, concentration, it is the same. Do you understand. But for pressure, we don't increase pressure by putting something, we increase pressure by decreasing volume. By decreasing a volume, for example we are 19 here. If we cut this class into half and put the 19 of us inside, we have decreased the volume, but we are still 19. We have more chances to collide and have effective collisions. Do you understand?
Learners	Mm
Learner	I did not hear that; can you please repeat?
Mr Brown	You didn't hear me?
Learner	Yes.
Mr Brown	I am saying for pressure we only apply it when dealing with gases. Pressure is almost the same as concentration, but pressure is dealt with when gases are involved. How do we increase pressure? We increase

	pressure by decreasing the volume. Isn't that everything reacts in a container. For concentration, we increase it by adding the reactants, isn't? We increase pressure by decreasing the volume. For example, this is the original volume. We want to increase pressure of this class; we will decrease the volume. We can move you here to the mobile classes or we cut this side of the class. By doing so, there will be more chances for Learner A to touch Learner B (learners laugh) If there are more chances of learner A to touch learner B, there will be more chances for effective collisions (Learners laugh). There will be more chances of learner A and B forming products. We are prophesying here, you, see?
Learners	Mm
Mr Brown	Let us look at this paper with the four small blocks. Whenever you are asked about the factors affecting the rate of reaction, I have added no paragraph.
Learner	I didn't get this one.
Mr Brown	You didn't get this one, right? Okay, I never wrote a paragraph, right?
Learners	Mm
Mr Brown	So now whenever you are asked to explain a factor affecting the rate of reaction, I do not expect a paragraph. I expect you to answer in point form. Do you hear me?
Learners	Yes
Mr Brown	Now let us look at number 3, we started with temperature, right? In these four blocks, we are explaining the factors in terms of the collision theory. In each block, there are four points meaning there is a maximum of 4 marks in this question. Do you understand?

Learners	Mm
Mr Brown	Increasing the temperature, point number one, according to the collision theory, when you increase the temperature the average kinetic energy of the particles increases because energy is equal to ½mv^2. The average kinetic energy of the particles increases. If the average kinetic energy of the particles since E is ½mv^2 which is E_k, the kinetic energy, increasing this one, this is a constant, right?
Learners	Mm
Mr Brown	It means you are increasing the velocity or speed. If I say run in this class, would you not bump into each other?
Learners	We will
Mr Brown	You will, right?
Learners	Mm
Mr Brown	By hitting each other there are more chances of effective collisions, right?
Learners	Mm
Mr Brown	By more effective collisions, there are more chances of reacting. The average kinetic energy of the particles increases. Point number 2, more particles have sufficient kinetic energy. This is almost the same, The third point, more effective collisions per unit time. The last one, the reaction rate increases. So, increasing temperature increases the rate of reaction. Do you understand?
Learners	Mm

Mr Brown	How about decreasing the temperature? By decreasing the temperature, you come back to these 4 points again, vice versa. The average kinetic energy of the particles decreases, right?
Learners	Mm
Mr Brown	Point number 2, less particles have sufficient kinetic energy. Point number 3, Less effective collisions per unit time. That per unit time is important. Lastly, the reaction rate decreases. The second one will be concentration. Increasing concentration, more particles per unit time. In that volume of washing machine, you added two scoops, you were increasing the number of particles in that volume. By so doing, more particles collide with the correct orientation, right?
Learners	Mm
Mr Brown	And more effective collisions per unit time. Can you see that part repeats itself? Its repeats, right?
Learners	Mm
Mr Brown	More effective collisions per unit time, reaction rate increases, right?
Learners	Mm
Mr Brown	Whenever you decrease concentration, you will have less particles per unit volume. Less particles collide with correct orientation, less effective collisions per unit time. Reaction rate decreases, right?
Learners	Mm
Mr Brown	We then go to surface area. More particles are exposed, more particles collide with correct orientation, more effective collisions per unit time. Again, it repeats, right?
Learners	Mm

Mr Brown	Then reaction rate increases. Again, it repeats. Meaning increasing the surface area increases the rate of reaction, right?
Learners	Mm
Mr Brown	Then for a catalyst, a suitable one, number four. A catalyst provides an alternative path with lower activation energy. What a catalyst does, remember we said it doesn't take part in the reaction, but it speeds up. That which will be well cooked under 100 degrees Celsius, it will then be well cooked under 50 degrees Celsius. So, it lowers the activation energy. Activation energy is the minimum energy required for reactants to react. By lowering the activation energy, more particles have sufficient kinetic energy, more effective collisions per unit time, the reaction rate increases. Now these things are arranged from one to four, right?
Learners	Mm
Mr Brown	Why are they arranged like this? Surface area, more particles are exposed, right?
Learners	Mm
Mr Brown	There on concentration, more particles per unit volume. It is almost the same, right?
Learners	Mm
Mr Brown	The last three are the same for concentration and surface area. Do you understand?
Learners	Mm
Mr Brown	Then you come to temperature and catalyst, the only difference is the first points. For temperature, the average kinetic energy of the

	particles increases. For catalyst, it provides the alternative path to lower the activation energy. The rest are the same. Do you hear me?
Learners	Mm
Mr Brown	I have arranged these one's for you to have a way of knowing them, so you don't forget them. You will say am helping you memorise this, that's your business. Now this paper, you will cut it in half and give it to your peer. What's wrong? The period is not over yet. I am short of copies. Go make copies of this document (instructing a learner). Let's do this one as a classwork, its simple there's multiple choice questions. They are saying which of the following reactions in each of the following pairs, A or B will have the highest reaction rate. Give reasons for your answer. You have two pairs of reactions. You have two pairs of reactions, right?
Learners	Mm
Mr Brown	They are not short. The numbering has been cut here. You know how this thing is, there is 1 and there is A and B, the first two, right?
Learners	Mm
Mr Brown	The one in number 3, its 2 A and B ne.
Learners	Mm
Mr Brown	The fifth one it's 3 A and B and so forth. This classwork, paste it after this one. And paste it after this piece I will give you now that says rates of reactions. You first paste the two I gave you at first and this one becomes your classwork. Do you see how this thing goes?
Learners	Mm
Mr Brown	(pause) Guys I need you to explain using the Collision theory, meaning that for each question you select an equation then check the

	points, 4 points. The activity involves different factors. There are different factors in those questions. I need you to explain using the collision theory. *(Learner's writing: from 01:07:08 to 01:15:56)* The key is in the bracket isn't? The key for these questions is in the brackets, right?
Learners	Mm
Mr Brown	*(Learners are writing: from 01:16:06 to 01:23:22)* Are you done? Guys, the key is in the bracket isn't?
Learners	Mm
Mr Brown	What is this?
Learner	It's a pressure.
Mr Brown	Kilopascals…. (Learners laugh). Kilopascal is the unit. Pascal is the unit for pressure isn't?
Learners	Mm
Mr Brown	If you can see the reactants and products, they are all gases isn't? If there is pascal, we talk of pressure isn't? Then if there is pressure, we use which block from that document I gave you? We use this one of concentration, isn't? Because I said concentration is the same as pressure isn't? Is it school out? You are going home to rest now? We have number 1, 2, 3, 4 and 5. (pause) You are done, right? Okay, if you are done, let's do the first question. They are saying which of the following reaction pairs, A or B, with the highest reaction rate. Give a reason for your answer. We decided to change that the reason must be given using the collision theory ne. Alright. We have zinc in solid state plus 2 HCL of 0.1 mol per decimetre cube. What is that? The 0.1 mol per decimetre cube.

Learners	Concentration
Mr Brown	Its concentration, isn't? It gives us Zinc Cl_2 plus H_2. The equation is the same but now in number B the concentration of HCL is now what? 0.2. What happened there, between A and B? There is an increase in concentration in number B isn't? If it's so, which equation will have the highest reaction rate?
Learners	B
Mr Brown	Its equation B isn't? Reason, because there is an increase in concentration. Then you go to that paper and explain using the Collison theory. You go to increase in concentration isn't? Increasing concentration there are more particles per unit volume, right? Point number 2, more particles collide with correct orientation, right? Number 3, more effective collisions per unit time, right? Point number 4, reaction rate increases. That's it, isn't? Then the second one, what is the factor there? Its temperature ne. One equation is at 50 degrees Celsius, and the other is at 20 degrees Celsius, right? Which one will have the highest reaction rate?
Learners	A
Mr Brown	It will be A isn't? Why? Because it has higher temperature. Okay, it's A, right? They have increased temperature for A. If they have increased temperature for A, again you refer back to that paper where you explain according to collision theory. Increasing temperature increases the average kinetic energy of the particles. More particles have sufficient kinetic energy. More effective collisions per unit time. Reaction rate increases. Four marks for nothing, you see? You go to the third one, here what is the factor?
Learners	Surface area

Mr Brown	I2 is in pallet form and the second one is in crushed form The factor is surface area. Which one has higher surface area?
Learners	B
Mr Brown	It means B has a higher reaction rate isn't? Again, you go to that piece of paper and explain. For surface area, what does it say?
Learners	Learners read: More particles are exposed. More particles collide with correct orientation. More effective collisions per unit time. Reaction rate increases.
Mr Brown	Clap hands for yourselves. Okay the fourth one, what is the factor there? Again, its surface area why? Because the second one is powdered. The reason is the same as the one we have just stated isn't. If ever you are wrong on the 4th one and correct on number 3, mark yourself wrong in number 3 (Learners are exclaiming). How can you identify the other one to be surface area and fail to identify the powdered one as a catalyst? How can you do that? Its surface area again. One magnesium is powdered, and the other one is ribbon, right? Same explanation. Or number 4, the one with a higher surface area is the powdered one, which is A. Number 5, here we talk of pressure. We have 300 Kilopascals and 150 Kilopascals. Which one has higher pressure?
Learners	A
Mr Brown	It's A isn't? Yes. A has a higher pressure. Since we are talking about pressure, the explanation will be the same as if you are explaining for concentration. You will say there is an increase in pressure where more particles per unit volume, more particles collide with correct orientation, more effective collisions per unit time and reaction rate

	increases isn't? You have marked yourselves with a pencil? Any questions? We will see each other when?
Learners	Saturday
Mr Brown	Saturday? (Learners laugh) Tomorrow its Thursday isn't. Since its Thursday, what happens?
Learner	We are eating samp. (Learners laugh)
Mr Brown	Since its Thursday tomorrow, we are starting at 06H30. It's hot now
Learners	Haa
Mr Brown	Okay, go to break.

Appendix L: Lesson observation (Post intervention)

Participant pseudonym: Mr Jones **Observation date: 29 October 2021** **Observed by: Nomfundo Radebe** **Topic taught: Organic Chemistry** **Lesson duration: 67:21**	
Mr Jones	Can you please open the windows, the rain poured your clothes are wet…. Alright let's see, are you done?
Learner	Yes
Mr Jones	Alright let's get started and see how you have responded to the questions. Alright let's do question 2 and see how you personally answered, Wait can you please bring all your papers forward don't waste time by writing grades and stuff just write your name (*Mr Jones collecting the learner papers and distributing them amongst them for peer marking*). Who else has their own papers? You all have something to mark right?
Learner	Yes
Mr Jones	Alright, let's mark. Let's start with question one by question 1, I mean question 2. Write down the IUPAC name of each of the following compounds. We all know how to name right? I don't think there is anyone who would have a problem with naming. Is there anyone with the problem when it comes to naming?

Learner	No
Mr Jones	We have revised naming for the longest of time even the strategies for naming, so what’s the name of that structure there? It’s what?
Learner	2,3-dimethyl….
Mr Jones	It’s 2, 3-dimethylpent-2-ene
Learner	2-ene
Mr Jones	Pent-2-ene right, alright it’s correct
Learner	Sir, some left out di-
Mr Jones	It’s one mark. Listen some of you left out di- you’ll get one some left out 2, you will also get one. Some of you might have written 2, 3-dimethyl-2-pentene this is incorrect who taught you this. We have spent a lot of time teaching this remember. Alright, number… all is clear on the first one, right? Alright, number 2 how do you name that structure? What's its name it's what?
Learner	3-bromo
Mr Jones	It’s 3-bromo-4. Is it methyl or ethyl
Learner	It’s methyl
Mr Jones	Methyl hexane. Alright wait Learner 1, what did they write on your paper? (checking the learners’ responses)
Learner	3-bromohexane

Mr Jones	Learner 2, what did they write on your paper? Learner 1, what did they write on your paper?
Learner	3-bromo-4-ethylpentane
Mr Jones	Pentane, do you see that they didn't write the correct ones? Is there someone who's calling me?
Learner	Sir, what if they wrote this (Learner referring on the paper they have)?
Mr Jones	Listen, what do we put in the middle of a number?
Learner	A line
Mr Jones	Is that clear? Please, don't forget that. Listen, here if you still don't understand the topic don't hide, feel free to say that you don't understand so that we can explain. Out of 100, 99 can get it correct and one person might get it wrong so you must raise up your hand and ask so that you will turn that 99 into 100. Then, when we name, we first check the longest chain. What was our longest chain there? If we can start counting from the left-hand side, you will count one up to 5 We have 5, right? Then when you count starting from the other side your account one to six you see when you count from this other side you will have 6 so the longest chain will be what will be six the other one will now become a branch is that clear. So, when you name, let's look at this (draws the hydrocarbon on the board), This is our branch, and this is our….
Learner	Sir, there is a double bond

Mr Jones	Is there a double bond, /no there is no double bond/ where are you seeing it from this question
Learner	Yes, there is one that is only bonded to three carbons
Mr Jones	There's no double bond there
Learner	There is none
Mr Jones	Which carbon are you referring to? let's count the carbons that are there number one we have CH3, the second one we have CH2 and the third one we have CH1 are you referring to that one or the next one you to it? I still don't see it. are you still saying that there's a double bond or there is none?
Learner	there is one Sir
Mr Jones	OK let me do this we have CH3 right and CH2, CHBr and CH2, CH3 and what else?
Learner	CH3
Mr Jones	So, this H will be bonded here, and this one will also be bonded here can you see that so there is no double bond? So now we want to name I said you must check the longest chain. some of you just counted 1 up to 5 and said that five carbons are you are your longest chain that's wrong/you must count everything right from different directions if you come from this side, you will get 6. So, 6 is the longest one and I said when you find the longest chain, what do we have here? we have hexane, do we have branches?
Learner	Yes

Mr Jones	Where do you start counting from the left right so if we start counting from the left that means on the third carbon, we have bromo and on the 4th one we have methyl. now when you name you know what to substitute, we have bromo and methyl on hexane. so, you check which one comes first does B come before M or B comes before M
Learner	B comes first
Mr Jones	B comes first right. That's how we name then we'll take B because we name it alphabetically. so, it would be 3-bromo-4-methyl hexane is that clear? Thank you. Now write down the structural formula of 4-methyl pentyne-2-ol all, now we are expected to write the structural formula of this (*writes it on the board*). The first thing here what's the first that you spot what's that?
Learner	The longest chain
Mr Jones	So, what is our longest chain?
Learner	Its pent
Mr Jones	It's pent, alright we go for the longest chain pent. here we are just drawing so don't try to draw complicated things just draw a straight one, pent has how many carbons?
Learner	it's 5
Mr Jones	Its 5 so we write 5 Carbons, (*drawing the structural formula*) What else is there?
Learner	There is OH

Mr Jones	We have OH right on which carbon?
Learner	Carbon number 2
Mr Jones	then you put that OH on carbon number 2. Then do you have branches there?
Learner	yes
Mr Jones	on which carbon?
Learner	on the 4th carbon
Mr Jones	on the 4th carbon we have a branch, which is what?
Learner	methyl
Mr Jones	It's CH3 right? then the rest will be the hydrogens. Is there something wrong?
Learner	Yes
Mr Jones	Where?
Learner	They are not looking for the structural formula but the condensed one so you must expand the CH3?
Mr Jones	Oh! so you guys are correcting the Mr Jones in front of a camera?
Learners	(*laughing*)
Mr Jones	If you want, you can also expand each but it's not it's not a problem you can also leave it like that (referring at OH). Alright next…. Use structural formula for all organic reactants and

	product to write a balanced equation for the preparation of propyl ethanoic, to which homologous series does this belong to?
Learner	Ester
Mr Jones	So, an Esther, what forms in Easter?
Learner	Alcohol and acid
Mr Jones	It's alcohol plus carboxylic acid. so, which one takes the form of the branch? And the other one takes the form of a parent
Learner	Alcohol
Mr Jones	This one becomes the branch (referring to alcohol), and this one becomes the parent (referring to carboxylic acid). So, which one is the branch when you read that name?
Learner	It's propyl
Mr Jones	We want to write down what, propyl ethanoate. So, propyl is what?
Learner	it's the branch
Mr Jones	It's our branch, right? so if it's our branch that means it's our alcohol and then ethanoate is our parent right, that means it comes from the carboxylic acid. Therefore, it is easy for you. I believe you can tell you can spot which one is your alcohol there which one is the alcohol.
Learner	it's propanol
Mr Jones	and then the carboxylic acid is what?

Learner	ethanoic acid
Mr Jones	Its ethanoic acid, right? It means there was a reaction between ethanoic acid and propanol to form what? propyl ethanoic. So, they're looking for the structure here right, so let's start by first writing the structure of alcohol it will be… (writes *propanol on the board*). Alright, how do you write the carboxylic acid?
Learner	Its C-C-C double bond OH
Mr Jones	It's like this right, to form what? we said that OH will react with what? with H. this one will join there (referring at OH), then this will form (*writing the structure of propyl ethanoate on the board*) …. That's it right? then what else is left?
Learner	Water
Mr Jones	There will be water, right? so that means it will be plus H2O and those who want to expand it can expand it, as they said they are looking for the structural formula.
Learner	There is a condition that we must write there, Sir
Mr Jones	We should write the condition, and the condition is H2SO4
Learner	We should also include condensation
Mr Jones	Is there really a need to include condensation? So, we are done right? That was 10 marks, so 10 Marks is 3% plus in the exam. Then let's go for the next one, question 3. We will finish this one quickly, right?
Learner	Yes

Mr Jones	The boiling point of 4 organic compounds represented by the letters ABC and D are given in the table below. We have A propane. maybe I must just draw it (*Draws the table on the board*). Don't skip questions such as these ones, these ones are questions where you must collect marks. Actually, the first few questions are not challenging. Challenging questions you'll get them around question 7. They're only challenging but not impossible. Define the term boiling point. Someone will go to an exam without knowing how to define boiling point. please don't be that kind of person, it's an abomination. The definition it's a straightforward definition very simple. Learner C, how is it defined?
Learner	It is a temperature at which the vapor pressure is equal to the partial pressure
Mr Jones	You see? that's correct! then which one of compounds of A or B has the higher vapor pressure? The first thing that you must understand here is what is? vapor pressure. what is the relationship between vapor pressure and boiling point? Learner D, which one is it? yes, we want a reply from you because you are disturbing the class by talking. Which one of these compounds, A or B, has a higher vapor pressure? they've written B but what do you think is the answer?
Learner	A
Mr Jones	You have written A as your response? There's someone who had their hand raised up, Learner C. Which one is it? Is it A or B? You are also saying that its B. So, Learner E, is there anyone that

	understands the relationship between boiling point in vapor pressure?
Learner	Yes
Mr Jones	Who is it? can you please explain to for us, preferably a female?
Learner	Boiling point is inversely proportional to vapor pressure
Mr Jones	In other words, when boiling point increases vapor pressure decreases. So, let's check, between A and B whichever one has a higher vapor pressure it means it will have a low polling point. Which one has a low boiling point there?
Learner	it's A
Mr Jones	A has a low boiling point compared to B. it means A has a high vapor pressure compared to B, so the answer is A, Learner F did you get that? alright. An unknown straight chain of alkane has a boiling point of -0, 5 degrees Celsius. Use the information in the table to write down its IUPAC name. What is the IUPAC name here? you will just predict right? they have given you a boiling point which is negative 0, 5. What can be the IUPAC name there?
Learner	Butane
Mr Jones	It's butane, right? because the boiling point is -0, 5, It's between these two *(pointing at the compounds on the Table*) and if you check here, this is propane and this is pentane, what's there in between is butane, right? and they've told us that it is a straight-line chain which is an alkene, no branches, straight chain. is that clear? Compound B and C are structural isomers. What is a structural isomer? Define the term structural isomer

Learner	A compound with the same molecular formula but different structural formula
Mr Jones	Thank you. Please, go and write that in your exam. What type of structural isomers are B and C?
Learner	Chain isomer
Mr Jones	It’s a chain isomer. There is no need for me to write on the board because you are writing there. Explain why compound B has a higher boiling point than compound C. Learner G, can you explain why Compound B has a high boiling point compared to C? what could be the cause or reason? How many marks are there? its 3, right? so let's try. what is the first reason? The obvious one
Learner	The longest chain
Mr Jones	It has the longest chain, and C?
Learner	It is branched
Mr Jones	It is branched right? You can just say B is a straight chain and the other one is branched right? it’s a mark. What’s another reason?
Learner	The longest chain needs more energy
Mr Jones	The longest chain needs more energy, right? There’s something I’ve seen. Can we please normalize using overcome instead of break? Is that clear? you understand what I’m talking about right? So, what would it be?
Learner	More energy is needed to overcome the intermolecular forces

Mr Jones	The intermolecular forces between what? On B we need more energy to overcome the molecular forces than on C. What else can you give them? What else can you say? what else is there?
Learner	Sir, what if we can say that they fall under different classes of forces like London forces?
Mr Jones	Yes, you can say that. No wait, they are all London forces. so how are you going to compare them? They are all in one cluster. What else can you say? Alright, let's look at this, which factor did they use there? It's surface area which has been increased. When do you have surface area being increased like for instance when looking at the carrot that has been chopped or a whole one?
Learner	The whole one
Mr Jones	No, the chopped one, right? Alright let's check the next one. Explain the difference in boiling points of B and D referring to intermolecular forces and energy in your explanation. This one is more specific right? They want you to check the intermolecular forces between the two and the energy required. What is happening on B? B and D are two different things, right? Now you can say what you wanted to say about forces. B has what?
Learner	London forces
Mr Jones	London forces, right? Then D has what? It has hydrogen bonds, right? So please mark there. Then what is the second one? Please make sure that when answering you don't skip anything because you will lose marks. energy is the last one, right? where is more energy is required?

Learner	(*inaudible*)
Mr Jones	That's what we have said right? London forces. These things are still the same. please familiarize yourself with explaining. please explain let's hear
Learner H	Compound B has London forces and compound D has hydrogen bonds, so hydrogen bonds are more strong than the London forces. So, to break hydrogen bonds more energy would be required So that's why compound B will have a higher boiling point.
Mr Jones	That will give you your full marks. Did you hear him? Listen please, make sure that you don't repeat the same information that we give you on the question. Give us something new. Next question. Yes, you can use a table but remember that we're using point form for the explanation. Propene or prop-1-ene is an unsaturated hydrocarbon and compound X is a saturated compound reacting with bromine, as represented by the incomplete reaction below. Some of you are busy laughing there at the back. We have reaction one, what's there in reaction 1? we have prop-1-ene + Br2 -, then reaction 2 which is X+ Br2 - 2bromobutane + Y. why is prop-1-ene classified as unsaturated? Learner D, what is the answer?
Learner	it has multiple bonds
Mr Jones	Because it contains double bonds, that's why we say they are unsaturated. that's the simplest answer, right? Can you guys please calm down. what type of reaction that takes place in reaction 1?

Learner	its addition reaction
Mr Jones	It's an addition reaction because we are moving from propene. Listen even though they didn't show us what's happening, but we know 2, and there is an idling 2 there, right? you just take it and use it. Alright, in soccer, a team can't play with 9 players, they must be whole, so when there are 2 players even when that they are not yours you let them play. Reaction 2?
Learner	substitution
Mr Jones	it's a substitution, why substitution? we don't know what X is, but whatever it is, it does not form only one product. if this was addition reaction, we would only have one product right, so now we are having 2 on the left-hand side and 2 on the right-hand side, which show that there was just a substitution of… there has been an exchange of something. so, write down the structural formula of the product which is formed in reaction 1. there is a rule used there. you must first draw this before adding the other ones, there are 3 carbons right and a double bond (*drawing the structure on the board*). From here, because we only Br, we will just write it here. If it was HBr what would happen here? H would be bonded in a section where there is H and Br would come here *(referring at the structural formula drawn*). is that clear? from this you will get 2 marks
Learner	Sir, you must remove the double bond
Mr Jones	oh, alright I was just giving an example. Alright, write down the reaction condition needed in order for reaction 2 to take place
Learner	heat

Mr Jones	heat or sunlight. By sunlight we referring to the one supplied by the sun
Learner	Sir, so what if they only wrote heat?
Mr Jones	Yeah, you can give them a mark, I believe you are marking right? use a pencil. write down the IUPAC name of reactant X. let's try to draw reactant X. look at this, there are 4 carbons, right? what is your reactant X?
Learner	its butane
Mr Jones	It seems useless to draw this, but let me write the reaction in full, we have 4 carbons + Br2, and so what happened here, one hydrogen here was swiped with bromide, so one bromide came here, and the H came here, and we now have HBr, hydrogen bromide. write down the name or formula of product Y
Learner	Hydrogen bromide
Mr Jones	so, if you don't want to write hydrogen Bromide you just write HBr. During both reactions, 1 and 2 the colour of the solution changes from reddish brown to colourless. In which reaction does this de-colorization occur faster? the first thing we must know is which reaction is it.
Learner	its reaction 1
Mr Jones	Its reaction 1. why do you say its reaction 1? Reaction 1 needs less energy compared to reaction 2, substitution is harder than placing things. If they can give you a box of a TV, and they say put this TV in the box it will be easy right? But if they put different appliances and they say exchange their boxes that will

	require more energy. Write down the IUPAC name of the major organic product. Oh, I have jumped a page here.
Learner	yes
Mr Jones	2-bromobutane can undergo either elimination or substitution, in the presence of a strong base like sodium hydroxide, which reaction will mostly take place when 2-bromobutane reacts in the presence of heated concentrated sodium hydroxide in ethanol? Choose from substitution or elimination
Learner	its elimination
Mr Jones	its elimination, so write down the IUPAC name of the major organic product which is formed when we eliminate 2-bromobutane. What will happen, what its name?
Learner	2-bromobutane
Mr Jones	No, this is not 2-bromobutane, here is 2-bromobutane (*writing it on the board*). So, when you eliminate, what will be moved? what will be major? what will be its name? we have 2 names, its either it will come this side or this side. so, for the first one we want the name of it when we start from this side.
Learner	2-bromo
Mr Jones	No, it's not 2-bromobutane. You have removed hydrogen. it seems like you were not listening when I did these annotations, you were not listening. now you are seeing a double bond, what will be the name? tell us, what did they write? what's the name (*asking learners individually*)
Learner	2-bromo

Mr Jones	No, it can't be 2-bromo because this structure is under elimination. Hr and hydrogen will be eliminated, what must be left is a double bond right?
Learner	its butene
Mr Jones	its butene
Learner	But Sir you didn't say so
Mr Jones	don't you have a question paper there? Yaa, you are tired. what do you say about this? Use the structural formulae for all organic reactants and products to write a reaction, a balanced equation for the reaction between 2-bromobutane and diluted sodium hydroxide. write down the name of the type of substitution reaction. its hydrolysis. so do it you see there is no space to write there for me to write
Learner	You can wipe
Mr Jones	who said that? please come wipe for us. Alright, what's reacting here (*writing 2-bromobutane on the board*) plus what?
Learner	NaOH
Mr Jones	NaOH. By just writing this you get a mark, then how will the reaction proceed?
Learner	OH will be attached while Br is detached
Mr Jones	You know how substitution reaction behaves right. so, it means we will have this (*writing the structural formula on the board*), what changes is these 2 (*circling at OH and Br*). Is that clear?

	once you are substituting something, this must happen so what will be having here? we will have NaBr and here?
Learner	OH
Mr Jones	OH, right? so if you want to expand it you can. then what’s left there?
Learner	the condition
Mr Jones	(*Writes it on the board*) then you get your marks right, we are done right.

Appendix M: Field notes of a workshop

Workshop topic: Chemical Equilibrium and Rates of Reactions

Workshop no: 7

Workshop date: 17 September 2021

Workshop Platform: Microsoft Teams

Notes written by: Nomfundo Radebe

- Workshop was conducted on a Friday and learners were to write a Chemistry paper on this topic.
- All the novice teachers who are participating in this study were present and attended the full session.
- Focus is on how the teacher can help the learners to answer the questions so that all learners are able to earn marks in each question. The facilitator emphasised that they do not necessarily have to get the full mark but must get at least 3 marks in a 7 marks question.
- Teachers were strongly encouraged to use the examination to guide their teaching.
- Facilitator explained that teachers must be wary of terms like excess as they indicate that some knowledge related to this will be required somewhere in the question.
- Teachers were taught how to prepare learners. To do this, the facilitator was going through questions papers from previous years, solving them along with the teachers. However, teachers were expected to 'pretend' to be learners, providing any answer the facilitator required.
- In each question addressed, the facilitator would break down the question into understandable bits. For example, identifying whether the reaction is balanced and interpreting the graphs before attempting to ask the questions.
- The facilitator explained the importance of revising and/or defining the key terms in the questions to be able to answer it. For example, what does it mean for a chemical to be in excess.

The facilitator explained that this is important because the learners sometimes answer the questions incorrectly because they do not understand the question and cannot make sense of the given scenario. Thus, teachers must explain the key concepts in the question before answering it.

- When the facilitator was requesting teachers to give answers or volunteer to participate in the workshop, they were mostly not responding. As a result, the facilitator ended up asking the officials to participate.
- Facilitator used everyday scenarios to explain key concepts such as cup of water and four teaspoons to explain the limiting reagent concept. Two teachers also shared their own analogies to explain the excess and limiting reagent concepts. With this, the facilitator kept encouraging the use of analogies as well as everyday examples and/or materials (such as Eno and water) to help learners understand the concepts.
- Facilitator emphasised that teachers must keep asking their learners about the information in the question so that they understand what is happening. The facilitator emphasises that this will help the learners to eventually understand.
- As the facilitator was working with the learners, she emphasized areas that learners normally find difficult to perform well on. As such, as the facilitator was going through the question papers with the teachers, she emphasized how most of these challenges can be addressed.
- Mr Brown and Jones actively participated in the workshop only once. Mr Smith did not actively participate in the workshop.
- Mr Brown was in the workshop for 1hour and 32 minutes.
- Mr Jones was in the workshop for 1hour and 36 minutes.
- Mr Smith was in the workshop for 1hour and 40 minutes.

Appendix N: Plagiarism Report

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ORIGINALITY REPORT

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