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Teaching Life Sciences on online platforms: a phenomenographic study

by

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Declaration

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Dedication

This thesis is dedicated to my parents, younger sister and late grandmother. Thank you for your continued love, support and encouragement.

Thank you, mummy, for being the first person I could call whenever a challenge came up or whenever I met an academic goal. Thanks for always listening and for all your advice throughout this academic journey.

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Abstract

This study explored Life Sciences pre-service teachers' experiences of learning Life Sciences on an online platform at university, and how they thought Life Sciences should be taught on online platforms in schools, using a phenomenographic approach. This topic is relevant because Life Sciences lecturers and teachers had to adapt their teaching strategies and representations to suit online platforms during the COVID-19 pandemic and subsequent university and school closures. Using semi-structured focus group interviews, 14 Life Sciences pre-service teachers were asked to describe the teaching strategies and representations used by their Life Sciences and Life Sciences methodology lecturers on online platforms. They were further asked to describe what teaching strategies and representations they thought Life Sciences teachers should use when teaching on online platforms in schools. The qualitative results described that the Life Sciences pre-service teachers perceived that their Life Sciences and Life Sciences methodology lecturers used teaching strategies such as synchronous teaching, asynchronous teaching and the flipped classroom approach. Representations used were visualisations such as PowerPoints, pictures and reading material, as well as digital educational technology such as online simulations and applications, e-books, YouTube videos and demonstration videos. Based on their experiences of learning Life Sciences on an online platform at university, the Life Sciences pre-service teachers suggested that the following teaching strategies should be used to teach Life Sciences on online platforms in schools: interactive and engaging synchronous teaching strategies, the flipped classroom approach and hybrid teaching. The Life Sciences pre-service teachers suggested that the following representations should be used to teach Life Sciences on online platforms in schools: visualisations such as PowerPoints and pictures, and digital educational technology such as experimentation software in the form of online simulations and applications. It was concluded that the Life Sciences pre-service teachers in this study perceived their Life Sciences and Life Sciences methodology lecturers as having developed Technology, Pedagogical and Content Knowledge (TPACK) when lecturing on online platforms. The Life Sciences pre-service teachers' TPACK was well established as they were able to perceive and understand how online platforms can be used to replicate and replace classroom-based practices, but they were not able to suggest ways in which teaching could be transformed online in a way that would not be possible in a face-to-face classroom.

Key terms: Synchronous teaching, Asynchronous teaching, Flipped classroom, Hybrid teaching, Online digital educational technology

List of abbreviations

B.Ed.	Bachelor of Education
PGCE	Postgraduate Certificate in Education
TPACK	Technology, Pedagogical and Content Knowledge
PCK	Pedagogical Content Knowledge
TK	Technology Knowledge
PK	Pedagogical Knowledge
CK	Content Knowledge
Demo	Demonstration
PhET	Physics Education Technology

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Chapter 1

Chapter 1 provides an overview of the study, namely Life Sciences pre-service teachers experiences of learning Life Sciences content on online platforms in university and their perceptions of the teaching strategies and representations that could be used to teach Life Sciences on online platforms in schools. An overview is provided by introducing the topic, providing background information on the topic, and by putting the topic into context. Furthermore, the research problem, research questions, purpose of the study and key concepts in the study were defined. In addition, the researcher's identity is described in the first person to show how the topic was inspired.

1.1. INTRODUCTION

On 12 March 2020, the World Health Organization (2020) declared COVID-19 a pandemic. Therefore, universities and schools across the globe had to shut down. In the South African context, the President called on all universities and schools to shut down and find ways to offer classes online as of 18 March 2020 as a precautionary measure (ENCA, 2020).

Although schools and universities re-opened in phases as of 8 June 2020, the COVID-19 lockdown was only lifted on 5 April 2022. Some universities in South Africa only resumed face-to-face classes on 25 July 2022 (Africa News, 2020; The Presidency, 2022; University World News, 2020). Therefore, many students would have experienced learning on online platforms for approximately two years.

This study explored Life Sciences pre-service teachers' experiences of learning Life Sciences on online platforms at university level. It also explored how they thought Life Sciences should be taught on online platforms in schools, based on their experiences. This topic was chosen as Life Sciences pre-service teachers would have had to study at least two years of their teaching qualification on online platforms. It was therefore interesting and necessary to explore their experiences of learning on online platforms

and how these experiences shaped their perceptions of how Life Sciences should be taught on online platforms in schools.

The participants in this study included Postgraduate Certificate in Education (PGCE) and third-year Bachelor of Education (B.Ed.) students. The PGCE students had never attended any in-person lectures in their current studies but may have experienced face-to-face lectures during their undergraduate studies. The third-year B.Ed. students started their degree in 2020, but only met their lecturers and peers for the first time in-person in June 2022. Data was collected from these participants through focus groups using online, hybrid and face-to-face interviews, due to varying COVID-19 regulations during this time. This study provided insight into their different perceptions of online Life Sciences education based on their own experiences and the different contexts of the focus group interviews they joined.

1.2. BACKGROUND AND RATIONALE TO THE STUDY

At the start of the COVID-19 pandemic, many teachers were caught in a predicament as they were required to immediately figure out how they could adapt their classroom-based practices to emergency online teaching (Luz, 2020). When moving towards emergency online teaching, teachers would have had to adapt their teaching strategies and representations to suit online platforms (Arcueno et al., 2021).

The literature review in Chapter 2 discussed teaching strategies that can be used on online platforms, including synchronous teaching, asynchronous teaching, the flipped classroom approach and hybrid teaching. Synchronous teaching is done in real-time with a live teacher. There is a pre-set time to log in to an online platform and learners can communicate directly with the teacher and their peers (Basilaia & Kvavadze, 2020; Shi & Morrow, 2006). Asynchronous teaching refers to lessons that do not take place in real-time. Instead, learners are provided with learning material on a regular basis to work through on their own, for example, pre-recorded lessons or at-home assignments. Teachers then provide regular support through online communication platforms, for example, via discussion boards, email or WhatsApp (Basilaia & Kvavadze, 2020; Biswas & Maiti, 2022; Reinholz et al., 2020; Skylar, 2009). The flipped classroom is a teaching strategy that uses a combination of both synchronous

and asynchronous approaches (Marina & Ridlo, 2021). The asynchronous component occurs when learning material is given to learners outside of class time. This is then supplemented with online, synchronous lessons (Marina & Ridlo, 2021). Hybrid teaching includes instruction where content is delivered both in-person and on online platforms (Basilaia & Kvavadze, 2020; Mossavar-Rahmani & Larson-Daugherty, 2007).

The literature in Chapter 2 also describes various representations that can be used to teach Life Sciences on online platforms. Some examples of representations that Life Sciences teachers can use include visual representations, such as diagrams, natural drawings, graphs, charts, tables, pictures, animations, or objects (Roth et al., 2006; Treagust & Tsui, 2013). Other representations that can be used for online teaching include digital educational technology like simulations, augmented reality, virtual reality, 3D printers, virtual labs and e-books (Daniel & Woody 2013; Emine et al., 2018; Treagust & Tsui, 2013).

To add to the body of knowledge above, in this study, Life Sciences pre-service teachers described the teaching strategies and representations used by their Life Sciences and Life Sciences methodology lecturers on online platforms. They also described their opinions on the best practices (teaching strategies and representations) for teaching Life Sciences on online platforms in schools.

1.3. CONTEXT OF THE STUDY

The context of the study was at a university in Gauteng province that was offering lectures on online platforms due to COVID-19 lockdown regulations. Data collection took place in the middle of the year 2022, when the country had minimal restrictions in place. During this time, the university was still offering online lectures, but some examinations were starting to be written in-person on campus (South African Government, 2024).

This context was very important to the purpose of the research. This study aimed to explore Life Sciences pre-service teachers experiences of learning on online platforms at university and their perceptions of how Life Sciences could be taught on online

platforms in schools. This meant that the participants of the study had to have some experience of learning Life Sciences content on an online platform. Furthermore, the context within which data was collected influenced the participants perceptions of online education. Namely, data was collected through focus group interviews conducted in various contexts based on the COVID-19 lockdown regulations at the time. These contexts included an online environment, a hybrid environment and an in-person environment.

The Life Sciences pre-service teachers in this study were either studying towards a B.Ed. degree or a PGCE. The B.Ed. qualification runs for a minimum period of 4 years. The B.Ed. students that participated in this study were currently in their third year of study. They were specifically studying towards a B.Ed. degree specialising to teach in the Senior Phase (SP) Further Education and Training (FET) phase. Teaching in the SP refers to teaching Grades 7-9, while teaching in the FET phase refers to teaching Grades 10-12. The subjects that the Life Sciences pre-service teachers were specialising in included Natural Sciences in the SP and Life Sciences in the FET phase.

Natural Sciences in the SP includes a Life Sciences strand called Life and Living. The Life and Living strand includes topics such as, the biosphere; biodiversity; sexual reproduction and variation; photosynthesis and respiration; interactions and interdependence within the environment; micro-organisms; cells; human reproduction and the circulatory, respiratory, and digestive systems (Department of Basic Education, 2011a). Life Sciences in the FET phase includes the following strands: Life at molecular, cellular and tissue level; Life processes in plants and animals; Diversity, change and continuity and Environmental studies. These strands cover topics such as cells, tissues and organs in both plants and animals; support systems and transport systems in plants and animals; animal and plant nutrition; biodiversity and ecology; micro-organisms; the systems of the human body and the impact of humans on the environment (Department of Basic Education, 2011b).

When teaching these topics, teachers need to meet various specific aims set out in the Curriculum and Assessment Policy Statement (CAPS) document, which is South Africa's National Curriculum Statement (NCS). The specific aims are knowing science, doing science and understanding the uses of science (Department of Basic Education,

2011a; Department of Basic Education, 2011b). In order to do science and apply scientific skills, teachers need to not only teach content, but also make their lessons very practical in nature.

Given the practical nature of Life Sciences, this study explored Life Sciences pre-service teachers experiences of learning Life Sciences content on online platforms in university. The Life Sciences pre-service teachers described the teaching strategies and representations used by their Life Sciences and Life Sciences methodology lecturers on an online platform, and the effectiveness of them in achieving practical teaching and learning outcomes. Based on their experiences, the Life Sciences pre-service teachers described their perceptions of the best teaching strategies and representations that could be used to teach Life Sciences on online platforms in schools. They were aware of the practical component of Life Sciences and carefully considered the teaching strategies and representations they suggested, so that practical teaching and learning outcomes could be met. The online teaching strategies described in this study included synchronous teaching, asynchronous teaching, the flipped classroom approach and hybrid teaching. Various representations were described, namely various visualisations and digital educational technology. The teaching strategies and representations are described in detail in the concept list, literature review and Chapter 5 discussion.

1.4. RESEARCHER IDENTITY

My interest in online education during the COVID-19 pandemic stems from my own experience and background. In 2020, when the COVID-19 pandemic started, I worked as a Life Sciences teacher at a high school in Centurion. The school had to move towards online teaching very quickly in March 2020 when the first lockdown was announced (ENCA, 2020).

All the teachers were given a one-day crash course on the online platform, Microsoft Teams, the day before school closed indefinitely. Some of the things we learnt included how to schedule live online lessons, how to record lessons and how to set up online assessments. We also learnt about the tools available on Microsoft Teams such

as the chat function, screen sharing and using a white board. Other than the one crash course, it was up to each individual teacher to figure out ways in which they could teach online and meet all of their learning outcomes as effectively as possible.

As a Life Sciences teacher who was exposed to online teaching for the first time, I struggled with the practical nature of the subject. I had to be creative in coming up with ways to do scientific investigations and other practical work on the online platform. My solution was to record myself doing scientific investigations at home with cheap and readily available resources. As I became more comfortable with the online environment, I created assessments whereby learners were required to record themselves doing practical tasks at home and I also discovered simulations and applications that were helpful.

Prior to teaching Life Sciences on an online platform in 2020, I have experience in teaching Natural Sciences and Life Sciences in various schools in the Gauteng province. After teaching Life Sciences online in 2020, I went on to become a lecturer at a private higher education institution in 2021, where I currently lecture the modules Natural Sciences Education and Introduction to Education Research. In 2021 and early 2022, our teaching and learning model included both online and in-person lectures. In other words, we used a hybrid approach for teaching. The online lectures took place on the online platform called Blackboard Collaborate. Once again, I had to find creative ways to teach the practical content in the Natural Sciences module on the online platform. However, having in-person lectures made it easier to meet the practical learning outcomes.

My educational background includes completing a Bachelor of Sciences (B.Sc.) degree in Human Genetics, a PGCE and a Bachelor of Education Honours (B.Ed. Hons.) degree in Life Sciences Education. During my undergraduate degree, in my final year in 2016, I was exposed to asynchronous teaching and learning, due to protest action and a subsequent campus shutdown at my university. My lecturers would pre-record lectures for us to watch at our own pace, in our own time. They would then administer online formative assessments for us to complete. I remember feeling upset and disappointed about missing out on all the practical sessions that were scheduled, that could not take place because of the shutdown. During my PGCE year, I was not exposed to any online teaching and learning, but I did have a module where

I learnt about integrating online applications into teaching, mainly for assessment purposes. During my honours degree, all my lectures took place in-person. My dissertation explored how experienced Life Sciences teachers taught Botany related content in Life Sciences, in a traditional face-to-face context.

My academic and professional background, coupled with my passion for Life Sciences has led me to become curious about teaching Life Sciences on online platforms. More specifically, it led me to become curious about the teaching strategies and representations that can be used to teach Life Sciences content on online platforms. Furthermore, I became curious to find out how other lecturers addressed the problems associated with teaching on online platforms.

1.5. PROBLEM STATEMENT/ STATEMENT OF RESEARCH INTEREST

Due to the national school and university closures during the COVID-19 pandemic since 2020, many university lecturers, including Life Sciences and Life Sciences methodology lecturers, were caught in a predicament as they needed to immediately work out how they could adapt their classroom-based practices to emergency remote teaching on online platforms (Luz, 2020). There was therefore a need to explore how Life Sciences pre-service teachers perceived these lecturers' responses and adaptations to lecturing on online platforms. There was a need to explore how Life Sciences pre-service teachers experienced this shift and their subsequent perceptions of how they thought Life Sciences should be taught on online platforms in schools.

Literature on this subject has focused on various strategies that can be used to teach Life Sciences on online platforms, namely synchronous teaching, asynchronous teaching, the flipped classroom approach and hybrid teaching. It also describes various representations, namely visualisations and online digital educational technology, that can be used to teach Life Sciences on online platforms. No information on Life Sciences pre-service teachers' experiences of learning Life Sciences and Life Sciences methodology modules on online platforms, and their perceptions of how Life Sciences should be taught in schools, could be found. Therefore, this study aimed to fill that gap by exploring Life Sciences pre-service teachers' experiences and perceptions of the teaching strategies and representation

used by their Life Sciences and Life Sciences methodology lecturers on online platforms. The study also explored what teaching strategies and representations Life Sciences pre-service teachers thought should be used to teach Life Sciences on online platforms in schools.

1.6. RESEARCH QUESTIONS

This study aimed to explore the experiences of Life Sciences pre-service teachers of learning Life Sciences on online platforms at university, and how they thought Life Sciences should be taught on online platforms in schools, based on their experiences. The following research questions were explored:

Main question:

How do Life Sciences pre-service teachers describe their perceptions of best practice for teaching Life Sciences on online platforms in schools, based on their experience of learning Life Sciences and Life Sciences methodology modules on online platforms at university?

Sub-questions:

1. What teaching strategies and representations did Life Sciences pre-service teachers perceive to be effective when they were learning Life Sciences and Life Sciences methodology modules on online platforms at university?
2. What teaching strategies and representations do Life Sciences pre-service teachers perceive to be effective for teaching Life Sciences on online platforms at schools?
3. What are the advantages and disadvantages of teaching Life Sciences on online platforms, as perceived by Life Sciences pre-service teachers?

1.7. INTRODUCTORY OVERVIEW OF THE THEORETICAL FRAMEWORK

Koehler and Mishra (2009) explored a technological integration framework called Technological, Pedagogical and Content Knowledge (TPACK). It builds on Shulman's

framework of Pedagogical Content Knowledge (PCK) by including the aspect of technology. The PCK of a teacher can be defined as the teacher's ability to transform subject matter for the practice of teaching (Shulman, 1986).

Pedagogical Knowledge (PK) refers to a teacher's knowledge of strategies for teaching. This includes the processes, practices and methods of teaching and learning. A teacher with sufficient PK understands how learners construct knowledge and develop skills. Content Knowledge (CK) refers to a teacher's knowledge of the specific subject matter that needs to be taught. Technology knowledge (TK) refers to a teacher's ability to understand educational technology well enough to utilise it during teaching. Having sufficient TK means that a teacher is able to recognise when digital educational technology can be used to achieve a learning outcome and also the ability to continuously adapt to changing educational technology over time (Koehler & Mishra, 2009).

The multiple aims of this study include exploring Life Sciences pre-service teachers' experiences of learning Life Sciences modules on online platforms and how these pre-service teachers thought Life Sciences should be taught on online platforms in schools. Using the TPACK framework together with the phenomenographical design, another aim was to explore Life Sciences pre-service teachers' perceptions of their Life Sciences and Life Sciences methodology lecturers' TPACK when teaching on online platforms. This study also explored the TPACK of the Life Sciences pre-service teachers themselves when they suggested teaching strategies and representations that they thought would be best suited for online teaching of Life Sciences in schools.

1.8. INTRODUCTORY OVERVIEW OF THE RESEARCH METHODOLOGY

The methodological paradigm guiding this study was the qualitative approach. This allowed the researcher to understand human behaviour by focusing on the meanings that events had for the people involved. Not only did the researcher look at what people experienced but also attempted to understand their reality such as what they thought and felt. This methodology allowed for an in-depth understanding on the social reality experienced by the participants (Ary et al., 2006). More specifically, it allowed for an

in-depth understanding of how online Life Sciences education was experienced and perceived by Life Sciences pre-service teachers.

The research design used in this study was a case study together with phenomenography. The case study focused on a single unit namely, a group of Life Sciences pre-service teachers who experienced learning Life Sciences on an online platform in university. The case study used in this study was a descriptive one as it aimed to describe the phenomenon of online teaching within its real-world context. More specifically, it described the teaching strategies and representations used to teach Life Sciences content on online platforms, from the perspective of Life Sciences pre-service teachers. This will allow for an in-depth understanding on how Life digital educational technology could be integrated teaching strategies on online platforms (Ary et al., 2006; du Plooy-Cilliers et al., 2021).

This study also made use of phenomenography, which is a qualitative research design that aims to describe the different ways a group of people experience a phenomenon. The aim of this approach was to study the variation of the Life Sciences pre-service teachers' experiences of the phenomenon of online Life Sciences education. In other words, the focus of this approach was not the phenomenon of online Life Sciences education itself, but rather the variation in the Life Sciences pre-service teachers' ways of experiencing the phenomenon. It offered a second order perspective (Larsson & Holmström, 2007). This means that the focus of this approach was on the Life Sciences pre-service teachers' experiences and the variation in their experiences (Åkerlind, 2018). Furthermore, the Life Sciences pre-service teachers described how they perceived online Life Sciences education should be like in schools, based on their own experiences.

Purposive sampling was used to purposefully select 14 Life Sciences pre-service teachers who had experienced learning Life Sciences and Life Sciences methodology modules on an online platform at some point during their tertiary education experience (Han & Ellis, 2019). The Life Sciences pre-service teachers consisted of B.Ed. and PGCE students at the same university in Gauteng province. Permission was sought and obtained from the registrar and the Dean of the Faculty of Education at the university.

Information about Life Sciences pre-service teachers' experiences learning Life Sciences modules on online platforms and how they thought Life Sciences should be taught on online platforms in schools was achieved through conducting focus group interviews. Semi-structured focus group interviews helped to encourage the participants to speak about their experiences and allowed them to give concrete examples about how they thought Life Sciences should be taught on online platforms in schools (du Plooy-Cilliers et al., 2021). Three focus group interviews were conducted. The focus group interviews were be conducted either online, in a hybrid context or in person. This was dependent on the COVID-19 regulations and was scheduled at a time convenient to the participants. When the interviews were online, an online platform convenient to the participants was used namely, Microsoft Teams. When the interviews took place in person, a venue convenient to the participants was used namely, lecture halls at their university. Furthermore, all COVID-19 regulations at the time were followed. This included mask wearing, hand sterilisation, suitable social distancing and ensuring adequate ventilation.

While other qualitative interviews either focus on the participant or the phenomenon itself, the interviews in phenomenographic studies emphasise the relation between the participant and the phenomenon. Hence, the semi-structured interview questions were carefully constructed to allow participants to reflect on their experiences (Bruce, 1997; Yates et al., 2012). To secure a rich understanding of the participants' perspectives in the focus group interviews, they were given freedom to expand their understandings, and they were asked follow-up questions to explore interesting themes from their responses. When constructing follow-up questions, leading questions were not asked, nor were any new ideas introduced that had not been expressed by the interviewees. This helped to avoid collecting biased data (Åkerlind & Bowden, 2005). These focus group interviews were recorded and transcribed.

Qualitative content analysis was used in this study and 8 steps were followed namely, preparation and familiarisation of the data, defining the coding units, developing categories, testing the coding scheme, coding and categorising all the data, assessing the coding consistency, drawing conclusions and reporting the findings (du Plooy-Cilliers et al., 2021; Clarke, 2019; Clarke & Braun, 2014; Zhang & Wildemuth, 2009). Phenomenographic data analysis is iterative in nature. This means that identifying and labelling of categories took place multiple times, during which the initially formed

categories and their descriptions are refined and modified to reach a final set of categories, which best represented the qualitative variations of the phenomenon from the participants' responses (Han & Ellis, 2019). Categories of description were identified before and after data collection (Ary et al., 2006).

1.9. FOCUS OF THE STUDY

This study was focused on gaining an in-depth understanding of Life Sciences pre-service teachers' experiences of learning Life Sciences and Life Sciences methodology modules on online platforms at university. More specifically, the focus was on how the participants experienced, perceived and described the teaching strategies and representations used by their Life Sciences and Life Sciences methodology lecturers on the online platform, Blackboard Collaborate. Then, based on these experiences, this study was focused on exploring the Life Sciences pre-service teachers' perceptions of the best teaching strategies and representations that could be used to teach Life Sciences on online platforms in schools.

This study used a qualitative approach, therefore the focus was on an in-depth and insightful understanding of the phenomenon of online Life Sciences teaching, rather than just reporting on the teaching strategies and representations used. Since the focus was on gaining more insight into online Life Sciences education, the participants described their feelings about the teaching strategies and representations used by their Life Sciences and Life Sciences methodology lecturers, as well as their reasons for suggesting the teaching strategies and representations they thought were best for teaching Life Sciences on online platforms in schools.

Along with the methodology, namely qualitative research, the design, sampling method, data collection method and data analysis method also helped to focus the research. The design used in this study was a case study design, whereby the case was a group of Life Sciences pre-service teachers who had experienced learning Life Sciences and Life Sciences methodology modules on an online platform in university (Maree et al., 2016; Yin, 2009). The case study design was used along with a phenomenographical design that allowed for a second order perspective of the

phenomenon (Larsson & Holmström, 2007). This made it possible to explore teaching strategies and representations that Life Sciences pre-service teachers thought could be used to teach Life Sciences on online platforms in schools, based on their own experiences of learning Life Sciences on an online platform in university (Åkerlind, 2018; Larsson & Holmström, 2007).

The sampling method used in this study was the purposive sampling method which allowed for the purposeful selection of participants that met a set criterion (du Plooy-Cilliers et al., 2021). The criteria were that the participants had to be Life Sciences pre-service teachers who had experience learning Life Sciences and Life Sciences methodology modules on an online platform. Life Sciences pre-service teachers who were studying towards a B.Ed. degree or PGCE were selected to take part in the study and they were all studying at the same university in Gauteng province.

Focus group interviews were used to collect data from the Life Sciences pre-service teachers. Focus group interviews are group interviews (du Plooy-Cilliers et al., 2021). In this study, 14 Life Sciences pre-service teachers were divided and interviewed in 3 three focus groups, in 3 different contexts. The three contexts included an online context, a hybrid context and an in-person context. These three contexts helped focus the study even further, as they influenced how the Life Sciences pre-service teachers perceived the different teaching strategies and representations that are used to teach Life Sciences on online platforms. Since this study was qualitative in nature, the research conducted did not aim to be value free. Instead, emphasis was placed on gaining an understanding of the perceptions of the participants based on their experiences. This was also in line with the phenomenography design which allowed for a second order perspective of online Life Sciences teaching (Åkerlind, 2018; du Plooy-Cilliers et al., 2021; Larsson & Holmström, 2007).

Finally, the data analysis method used in this study was qualitative content analysis, more specifically thematic analysis. This method together with the phenomenographic design allowed for the data to be analysed in an iterative manner. This means that identifying and labelling categories took place multiple times, during which the initially formed categories and their descriptions were refined and modified to reach a final set of categories, which best represented the qualitative variations of the phenomenon from the participants' responses (Han & Ellis, 2019). This helped focus the study

towards the following categories: synchronous teaching, asynchronous teaching, the flipped classroom approach, hybrid teaching, representations and the advantages and disadvantages of online teaching and learning.

1.10. PURPOSE OF THE STUDY

The purpose of this study was to find out more about teaching strategies and representations used to teach Life Sciences content on online platforms. More specifically, the purpose of this study was to find out about Life Sciences pre-service teachers experiences of learning Life Sciences and Life Sciences methodology modules on an online platform at university, during the COVID-19 pandemic. Based on these experiences, this study aimed to explore the Life Sciences pre-service teachers' perceptions of what teaching strategies and representations could be used to teach Life Sciences on online platforms in schools. Furthermore, this study aimed to explore why the Life Sciences pre-service teachers perceived the online teaching strategies and representation for Life Sciences content in the ways that they did. Their reasons were justified by exploring their perceptions of the advantages and disadvantages of online teaching and learning in general and in the context of Life Sciences education.

1.11. CONCEPT CLARIFICATION

Phenomenography

Phenomenography is a qualitative research approach that aims to describe the different ways a group of people experience a phenomenon, offering a second-order perspective of the phenomenon. It focuses on human experience and the variation in experience (Åkerlind, 2018; Larsson & Holmström, 2007).

Online platforms

An online platform is a portal for educational content and resources that offers students, learners and educators everything they need in one place, namely, lessons (live and recorded), various educational resources and opportunities to meet and chat with peers. It also allows students, learners and educators to monitor educational progress (My Computer Career, 2023). The online platforms referred to in this study include digital educational technology that is used for teaching and learning.

Blackboard Collaborate

Blackboard Collaborate is a video conferencing tool that can be used in real-time. It is a platform that allows the user to add files, share applications, and use a virtual whiteboard to interact with others who join a live a session. It opens up in an internet browser, so that users do not have to install any software to join a session. In the context of this study, Blackboard Collaborate was used by the participants (Life Sciences pre-service teachers) to learn Life Sciences content online (ClickUp, 2024).

Microsoft Teams

Microsoft Teams is an online application used by various organisations. It is an online platform used for real-time collaboration, communication, meetings and material sharing (Microsoft, 2024). In this study, the Microsoft Teams platform was used to conduct focus group interviews as part of the data collection process.

Teaching strategies

Teaching strategies are the various strategies educators use in their teaching practice and cover a wide range of techniques. Effective teaching strategies require pre-planning, outlining learning outcomes, and providing feedback (NSW Government, 2023). Teaching strategies also refer to the method of instruction used by teachers to minimise misconceptions faced by learners (Mavhunga & Rollnick, 2011). Teaching strategies in the context of this study refer to the method of instruction used by Life

Sciences teachers and lecturers to minimise misconceptions faced by learners on online platforms.

Synchronous teaching

Synchronous teaching is done in real-time with a live teacher. There is a pre-set time to log in to an online platform and learners can communicate directly with the teacher and their peers (Basilaia & Kvavadze, 2020; Shi & Morrow, 2006).

Asynchronous teaching

Asynchronous teaching refers to lessons that do not take place in real-time. Instead, learners are provided with learning material on a regular basis to work through on their own, for example, pre-recorded lessons or at-home assignments. Teachers then provide regular support through online communication platforms, for example, via discussion boards, email or WhatsApp (Basilaia & Kvavadze, 2020; Biswas & Maiti, 2022; Reinholz et al., 2020; Skylar, 2009).

The flipped classroom approach

The flipped classroom is a teaching strategy that uses a combination of both synchronous and asynchronous approaches (Marina & Ridlo, 2021). The asynchronous component occurs when learning material is given to learners outside of class time. This is then supplemented with online, synchronous lessons (Marina & Ridlo, 2021).

Hybrid teaching

Hybrid teaching includes instruction where content is delivered both in-person and on online platforms (Basilaia & Kvavadze, 2020; Mossavar-Rahmani & Larson-Daugherty, 2007).

Representations

Representations refer to the tools or methods used to represent subject matter (Mavhunga & Rollnick, 2011). Some examples of representations that Life Sciences teachers can use include visual representations, such as diagrams, natural drawings, graphs, charts, tables, pictures, animations, or objects (Roth et al., 2006; Treagust & Tsui, 2013). Other representations that can be used for online teaching include digital educational technology like simulations, augmented reality, virtual reality, virtual labs, e-books and the tools available on online platforms (Daniel & Woody, 2013; Emine et al., 2018; Treagust & Tsui, 2013).

Digital educational technology

Digital educational technology for example, simulations, augmented reality, virtual reality, virtual labs, e-books and the tools available on online platforms, provides an immediate teaching and learning environment. Some advantages of digital educational technology include faster evaluation and more engagement. Digital educational technology helped keep educational systems running smoothly during the COVID-19 pandemic. It helped teaching and learning to continue conveniently from home (Daniel & Woody, 2013; Emine et al., 2018; Haleem et al., 2022; Treagust & Tsui, 2013). The digital educational technology discussed in this study includes online simulations, online applications, experimentation software, e-books, YouTube videos and Demo videos.

Visualisations

Visual representations may be referred to as visualisations. These can include diagrams, natural drawings, graphs, charts, tables, pictures, animations or objects used to portray theoretical and conceptual content. Multiple visualisations are used at once to help learners make comparisons for deeper understanding of content. Visualisations are important for learning, practicing and communicating content (Ainsworth, 2014; Eilam & Gilbert, 2014; Matthewson, 1999; Roth et al., 2006; Treagust & Tsui, 2013). Some visualisations discussed in this study include PowerPoint slides, pictures, videos and reading material.

Technological, Pedagogical and Content Knowledge

This construct builds on Shulman's framework of Pedagogical Content Knowledge (PCK), by including the aspect of technology. Teachers will have sufficient Technological, Pedagogical and Content Knowledge (TPACK) on an online platform if they manage to present content in an interactive and engaging manner by integrating digital educational technology into their teaching strategies and representations effectively (Koehler & Mishra, 2009).

Chapter 1 introduced the topic of Life Sciences experiences and perceptions of teaching Life Sciences on online platforms. The background information provided an overview of what previous literature discussed about the topic. This helped put the topic under study into context. Chapter 1 also highlighted the golden thread between the research topic, research problem, research questions and the purpose of the study.

Chapter 2: Theoretical/ conceptual framework and Literature Review

Chapter 2 explores previous literature on online teaching strategies, namely synchronous teaching, asynchronous teaching, the flipped classroom approach and hybrid teaching. It also explores various representations that can be used to teach Life Sciences on online platforms, namely visualisations and digital educational technology. Further to this, the advantages and disadvantages of online teaching and learning are discussed in various contexts.

Finally, Chapter 2 also explores the TPACK theoretical and conceptual framework guiding this study.

2.1. THEORETICAL AND CONCEPTUAL FRAMEWORK

Shulman (1986) developed the framework of Pedagogical Content Knowledge (PCK). The PCK of a teacher, represented in Figure 1 below, can be defined as the teacher's ability to transform subject matter for the practice of teaching (Shulman, 1986).

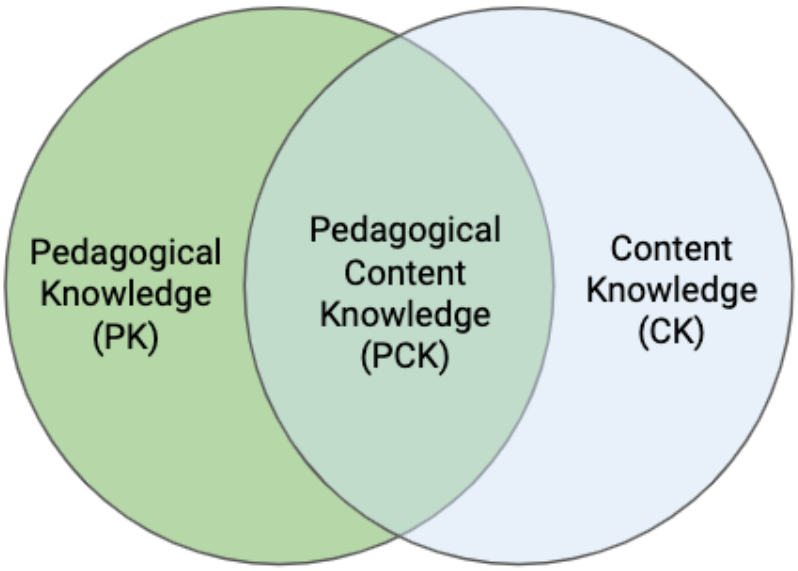

Figure 1: Conceptual framework for PCK (Shulman, 1986)

Koehler and Mishra (2009) developed a technological integration framework called Technological Pedagogical and Content Knowledge (TPACK), represented in Figure 2 below. It builds on Shulman's framework of PCK by including the aspect of technology.

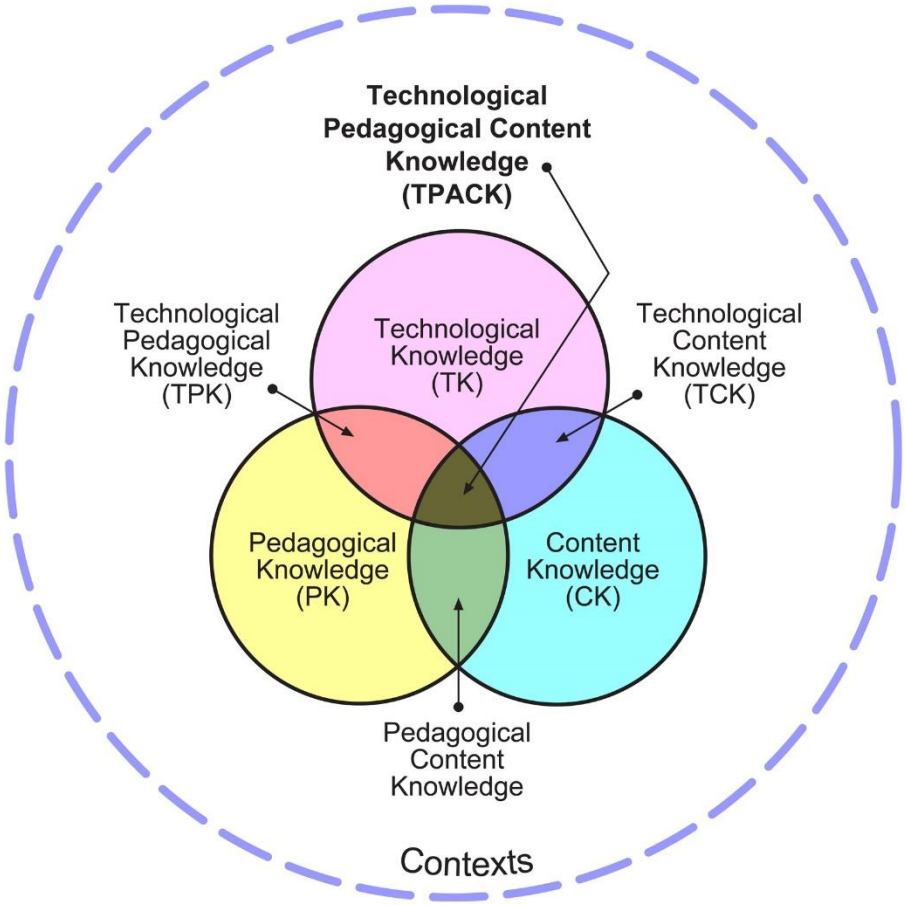

Figure 2: The TPACK framework and its knowledge components (Koehler & Mishra, 2009)

Pedagogical Knowledge (PK) refers to a teacher's knowledge of teaching strategies. This includes the processes, practices and methods of teaching and learning. A teacher with sufficient PK understands how learners construct knowledge and develop skills. Content Knowledge (CK) refers to a teacher's knowledge of the specific subject matter that needs to be taught. Technology knowledge (TK) refers to a teacher's ability to understand technology well enough to utilise it during teaching. Having sufficient TK means that a teacher is able to recognise that technology can be used to achieve a learning outcome and also has the ability to continuously adapt to changing digital educational technology over time (Koehler & Mishra, 2009). The technology referred

to in this study includes online digital educational technology like simulations, augmented reality, virtual reality, virtual labs, e-books and the tools available on online platforms (Daniel & Woody, 2013; Emine et al., 2018; Treagust & Tsui, 2013).

TPACK can be separated into Technology and Content Knowledge (TCK) and Technology and Pedagogical Knowledge (TPK). TCK refers to knowledge about linking technology with content (Jonassen et al., 2008). Teachers with good TCK who teach on online platforms should know their subject's content and be able to modify it with online digital educational technology. In other words, they should be able to use effective representations of the subject matter on online platforms. TPK refers to knowledge of technology that can be used to transform teaching strategies (Schmidt et al., 2009). Teachers who teach on online platforms should be able to use online digital educational technology to transform their teaching strategies.

Teachers are sometimes under the impression that the mere presence of online digital educational technology is sufficient for effective teaching on online platforms. However, they must be able to use online digital educational technology to transform their teaching strategies and their representations of concepts, to enhance their learners' learning experience (Koehler & Mishra, 2009). Teaching strategies are methods of instruction that teachers and lecturers use in their teaching practice. These methods of instruction cover a wide range of techniques and require pre-planning, outlining learning outcomes, and providing feedback (NSW Government, 2023). Teaching strategies are also used to minimise misconceptions faced by learners and students. Representations refer to the tools or methods used to represent subject matter for, example, pictures, analogies, models, demonstrations, videos and experiments (Mavhunga & Rollnick, 2011). Some examples of representations that Life Sciences teachers can use include visual representations, such as diagrams, natural drawings, graphs, charts, tables, pictures, animations, or objects (Roth et al., 2006; Treagust & Tsui, 2013). Other representations that can be used for online teaching include digital educational technology like simulations, augmented reality, virtual reality, virtual labs, e-books and the tools available on online platforms (Daniel & Woody, 2013; Emine et al., 2018; Treagust & Tsui, 2013). A teacher's ability to use online digital educational technology to transform their teaching strategies and representations effectively is an indication of a strong correlation between their PK

and CK with their TK. In other words, it leads to the development of their TPACK (Koehler & Mishra, 2009).

Teachers will have sufficient TPACK on an online platform if they manage to present content in an interactive and engaging manner. In other words, teachers should use online digital educational technology to transform their teaching strategies and representations effectively. They should ultimately display strong correlations between their PK and CK with their TK (Koehler & Mishra, 2009).

This study aimed to explore how Life Sciences pre-service teachers perceived their Life Sciences and Life Sciences methodology lecturers' teaching on online platforms and how they thought Life Sciences should be taught on online platforms in schools. In other words, they described how their Life Sciences and Life Sciences methodology lecturers adapted their teaching strategies and representations to suit an online platform and how they thought online digital technology could be used to adapt teaching strategies and representations for Life Sciences on online platforms in schools.

2.2. LITERATURE REVIEW

At the start of the COVID-19 pandemic, many teachers found themselves having to suddenly devise ways to adapt their classroom-based practices to emergency online teaching (Luz, 2020). Teachers were at the forefront in addressing the disruption to teaching and learning caused by the COVID-19 pandemic. They had to organise online teaching and learning processes while taking into account curriculum requirements as well as the availability of online resources (Arcueno et al., 2021). Many teachers had little to no knowledge and skills related to using digital educational technology on online platforms and had difficulty designing online lesson plans, learning materials and assessments (Ferri et al., 2020). As schools transitioned to online teaching during the COVID-19 pandemic, they also faced many challenges related to technology, for example, connectivity issues and unequal access to digital educational technology (Arcueno et al., 2021).

Despite the challenges of online teaching during the COVID-19 pandemic, online platforms provided a convenient means for communication between teachers and their learners. It gave teachers an opportunity to explore their creativity when planning online lessons to keep their learners engaged and motivated. Learners also got to explore and develop new skills, such as self-paced learning, self-regulated learning and self-discipline. This motivated learners to invest more towards their learning progress (Arcueno et al., 2021).

When moving towards emergency online teaching, teachers would have had to adapt their teaching strategies and representations to suit online platforms (Luz, 2020). Teaching strategies that can be used on online platforms include synchronous teaching, asynchronous teaching, the flipped classroom approach and hybrid teaching.

Synchronous teaching

Online teaching takes place either synchronously or asynchronously (Skylar, 2009). Synchronous teaching is done in real-time with a live teacher. There is a pre-set time to log in to an online platform and learners can communicate directly with the teacher and their peers (Basilaia & Kvavadze, 2020; Shi & Morrow, 2006).

Three critical considerations for creating productive synchronous online learning environments include social presence, cognitive presence, and teaching presence (Reinholz et al., 2020). Social presence refers to social connection within the online learning environment. This means that learners are able to build and maintain relationships with their teacher and peers, and engage in communication (Kozan & Richardson, 2014). Social presence is achieved when teachers talk about something other than the content, to build relationships with learners and to establish a comfortable online learning environment (Harrison et al., 2019; Seidel et al., 2015). This type of talk is necessary to alleviate issues such as social isolation (McInnerney & Roberts, 2004). An important consideration one needs to make when maintaining social presence during online synchronous lessons is that a learner's home context may become distracting, for example, learners may be sharing space with others,

taking care of children or the elderly, or may not have a safe space to engage (Jegede & Kirkwood, 1994). To promote equity during synchronous online lessons, teachers need to be understanding about their learners' individual circumstances at home and adjust their teaching strategies accordingly. This requires additional effort, as teaching on online platforms makes it difficult to have one-on-one check-ins with learners during class time (Reinholz et al., 2020).

The second consideration for creating a productive synchronous online learning environment is cognitive presence (Reinholz et al., 2020). Cognitive presence involves the teacher creating opportunities for their learners to explore, reflect and construct meaning (Garrison, 2007). Cognitive presence can be achieved when teachers build meaningful learning opportunities for their learners. Teaching strategies that can be used to achieve cognitive presence include facilitating discussions, problem-solving, reflection and laboratory activities. Discussions, problem-solving, and reflections are easier to implement on online platforms, while laboratory activities are more difficult to integrate into online teaching (Reinholz et al., 2020). In this case, it may be necessary to use an alternative representation for laboratory activities, such as computer simulations (Whitworth et al., 2018). Cognitive presence may be limited by learners not having equal access to technology for example, some learners may have slow internet speed, low connectivity, and limited access to working devices, video cameras and microphones (Ng, 2007). This unequal access to technology could limit learners' engagement and interactions online (Reinholz et al., 2020). It is also important to take into consideration that some learners may have learning barriers such as not being able to focus on a screen for long periods of time. This will also impact cognitive presence (Roberts et al., 2011).

Finally, teaching presence focuses on the ways that teachers make meaningful learning opportunities available to learners. This involves using a variety of different technologies to provide different opportunities for participation. Promoting teaching presence online can be difficult when compared with a physical classroom space, because typical actions like moving around a classroom to promote participation, are not possible (Reinholz et al., 2020). The capacity to effectively facilitate participation depends on a teacher's capacity and ability to use technology for teaching (Mishra & Koehler, 2006). Therefore, teaching effectively online may require sustained training and professional development (Rienties et al., 2013).

Social, cognitive and teaching presence are interrelated and must be considered together (Garrison, 2007). Reinholz et al. (2020) reported on some synchronous teaching strategies that lecturers in various disciplines used to maintain social, cognitive and teaching presence. These included re-establishing classroom norms, using student names, using breakout rooms, using chat-based participation and polling software, creating an inclusive curriculum and reducing content to maintain rigour.

When re-establlishing classroom norms, they would promote the use of the chat function and reactions (thumbs up, clapping and hand raising) on the online platform. They would also facilitate whole class or small group discussions with the help of polling software and breakout rooms. Two strategies that were reported as working well included the “go around the room” and the “five hands” strategies. The “go around the room” strategy was described as the lecturer going through the list of students and giving each one a chance to make a brief comment. The ”five hands strategy” was a rule applied that a student would only be called on to make a comment when five hands were raised. These two strategies were reported to increase participation on the online platform (Reinholz et al., 2020).

Reinholz et al. (2020) that many of the lecturers did not use student names when teaching online. This was a huge barrier to maintaining social presence on the online platform. The lecturers that did make the effort to use student names, found that it helped them become more socially conscious educators. They believed that it created a positive sense of belonging and success for each student in their online class. In other words, it boosted social presence. They reported that it was easier to use student names on online platforms, because they could simply read the names off the screen.

Many students tend to refrain from participating in whole-class discussions on online platforms. Therefore breakout rooms can be used to give students the opportunity to interact in smaller, more personal settings with their peers. This creats greater social presence (Reinholz et al., 2020). The lecturers in the study by Reinholz et al. (2020) moved between the breakout rooms, which gave more consistent, personalised attention to students. These breakout rooms and subsequent group work, helped in reducing isolation and provided students with social support when they were struggling or needed help with their work. They reported that the best way to utilise breakout

rooms, was to first give students a chance to discuss topics in their breakout groups, and then to bring those discussions back to the whole class. The lecturers also admitted that when they first started teaching online, they resorted to lecturing with no engagement or interaction. After getting used to the tools on the online platform, such as the breakout rooms, they were able to become more conscious about maintaining social, cognitive and teaching presence.

Chat-based participation was reported as a low barrier for students, compared to speaking up in online classes with their microphones switched on. It also helped students interact with their classes, even if they had limited access to specific types of technologies, such as devices with working microphones (Reinholz et al., 2020).

Reinholz et al. (2020) reported on how lecturers made use of polling software to increase participation, to enhance teaching presence and to promote equity in their online classes. A strategy that worked well was to invite students to access a poll and solve problems related to the class topic. Students would be given some time to work on the problems, and after most of the students completed the poll, the answers would be read and some ideas would be given on how to solve the problem. This software, provided students with an anonymous way of engaging and participating in the class, which was beneficial for those students who were not very comfortable sharing information to the whole class and allowed everybody to participate at the same time. Another strategy that worked well was using polling software in conjunction with chat-based participation. This was achieved by asking students a question and monitoring how many students responded over chat. This question was then followed up with a poll to give students who did not respond via chat, an additional opportunity to contribute to the class discussion.

Lecturers created an inclusive online environment by connecting their curricula directly to their students' lived experiences. This stemmed from the view that equity in an online classroom is not only reflected in the participation of students but also how a lecturer validates different ideas, identities, and cultures. Lecturers were very conscious about building a safe and inclusive online environment for their students (Reinholz et al., 2020).

Finally, content was cut to maintain rigour. Lecturers would carefully plan which material to cover during sychronous lessons, and which material could be give to

students to work through in their own time (Reinholz et al., 2020). This strategy relates to the flipped classroom approach discussed below in this chapter.

Teachers who teach synchronously on online platforms will have well-developed TPACK if they manage to present content in an interactive and engaging way. In other words, in order to have well-developed TPACK of synchronous teaching strategies, social, cognitive and teaching presence needs to be maintained on online platforms (Koehler & Mishra, 2009).

Asynchronous teaching

Asynchronous teaching refers to lessons that do not take place in real-time. Instead, learners are provided with learning material on a regular basis to work through on their own, for example, pre-recorded lessons or at-home assignments. Teachers then regularly provide support through online communication platforms, for example, via discussion boards, email or WhatsApp (Basilaia & Kvavadze, 2020; Biswas & Maiti, 2022; Reinholz et al., 2020; Skylar, 2009). Asynchronous teaching provides a flexible, self-paced learning environment for teachers and learners. It does not require real-time interaction as with synchronous teaching, but rather provides teachers and learners with the opportunity to share material and interact as frequently needed (Biswas & Maiti, 2022; Skylar, 2009).

Asynchronous teaching provides learners with a self-learning environment where they can take control of their own learning and complete learning outcomes at their own pace. However, with this freedom comes great responsibility, as learners need to be highly motivated and disciplined to do the work. Teachers can facilitate this by carefully planning their lessons in a way that provides learners with clear instructions and frequent support and feedback (Biswas & Maiti, 2022).

Designing asynchronous, online lessons requires teachers to develop new lesson planning skills compared to what they are used to using in a face-to-face context (Johnston et al., 2005; Mayer, 2014a). When planning and creating pre-recorded lessons, teachers need to ensure that information is presented in short, learner-paced segments; with conversational speech, instead of just using on-screen text; without

extraneous information; with high-quality pictures and animation; and with cues that highlight important information (Choe et al., 2019; Mayer, 2014b; Mayer & Fiorella, 2014; Mayer & Pilegard, 2014).

There are two broad types of pre-recorded lesson video styles, namely didactic and non-didactic video styles. The purpose of didactic videos is to teach the theoretical component of a subject, while the purpose of non-didactic videos is to supplement the instruction with a more practical component (Choe et al., 2019).

Examples of didactic videos include the Classic Classroom, Weatherman, Learning Glass, Pen Tablet, Talking Head, and Slides On/Off styles. The Classic Classroom involves the teacher using both a PowerPoint presentation and a chalkboard. The Weatherman is described as the teacher standing in front of a large green screen projecting content. One downside of the Weatherman is that the teacher cannot draw or write in real-time. The Pen Tablet style is described as the lecturer using an interactive pen tablet, with which they can point with the stylus and draw directly on the lesson slides. The Talking Head style video is similar to the Pen Tablet, but it enables the teacher to actually be in the video, appearing as a 'talking head'. The Slides On/Off style is similar to the Talking Head style, except that either the lesson slides or the teacher are displayed separately. The Learning Glass is very interesting as it utilises an LED-illuminated low iron glass that functions as a whiteboard, and it appears in front of the teacher. It should be noted that the Learning Glass can only be utilised by those who can afford it (Choe et al., 2019).

Examples of non-didactic videos include the demonstration (Demo) and Interview styles. The Demo and the Interview do not include prepared lesson slides. Instead, the Demo style captures the teacher doing practical tasks such as scientific experiments. The Interview style captures the teacher sitting in front of a digital screen, in conversation with an off-screen interviewer. The interviewer asks a question that the teacher addresses while displaying relevant information on a digital screen. The questions are displayed as text in full-screen mode before each response (Choe et al., 2019).

Skylar (2009) reported how Education lecturers used asynchronous methods for teaching on an online platform. Lecturers would upload learning materials such as PowerPoint slides and other reading materials. The resources were organised into

weeks, with a corresponding online quiz at the end of each week. Lecturers were able to facilitate this process through the use of emails and discussion boards. Discussion boards were also used to facilitate group discussions between students. This strategy was perceived as very effective by the students. They reported that learning on their own, asynchronously, greatly improved and developed their technological skills. However, they expressed their need for some interaction in the form of live, online classes. In other words, they suggested that asynchronous methods together with synchronous methods be used for optimal learning to take place. This is in line with the flipped classroom approach discussed below.

In order to have well-developed TPACK of asynchronous teaching methods, teachers need to be able to use digital educational technology to its full potential for example, the different types of videos mentioned above. Digital educational technology can be used to facilitate learning, by providing an immediate teaching and learning environment. If utilised for asynchronous teaching properly, it leads to faster evaluation and more engagement on online platforms (Daniel & Woody, 2013; Emine et al., 2018; Haleem et al., 2022; Koehler & Mishra, 2009; Treagust & Tsui, 2013).

Flipped classroom approach

Online teaching takes place either synchronously or asynchronously (Skylar, 2009). However, when teaching online, a combination of both synchronous and asynchronous teaching methods is recommended, because it broadens learners' online learning experiences and closely resembles the interactive experience of face-to-face classrooms (Offir et al., 2008; Skylar, 2009). The flipped classroom is a teaching strategy that uses a combination of both synchronous and asynchronous approaches (Marina & Ridlo, 2021).

The asynchronous component occurs when learning material is given to learners outside of class time. This is then supplemented with online, synchronous lessons (Marina & Ridlo, 2021). For this approach, teachers are encouraged to give learners various options to learn material, for example, from books, videos, audio files, or any other types of materials that cover a topic. Afterwards, learners are expected to

demonstrate understanding of this content through activities and discussions that take place during live class time (Edudemic, 2015; Jeffries & Hugget, 2014; Russell & Hollander, 1975; Sergis et al., 2015)

The flipped classroom helps learners to practise self-learning, making them more aware, responsible and independent (McCarthy, 2016; Rindaningsih, 2018). It allows them the opportunity to work through learning material at their own pace and then to apply what they have learned in class (Enfield, 2013; Karras, 2022). In the flipped classroom, direct instruction moves to the individual learning space, while the group space (live class time) is transformed into a dynamic, interactive learning environment, where the teacher guides learners as they apply concepts and engage creatively in the subject matter (Malto et al., 2018).

Malto et al. (2018) reported that Grade 10 Life Sciences teachers implemented a flipped classroom approach using three stages. During Stage 1, learners were given guide questions to help them focus on important points as they watched pre-recorded lectures that were uploaded online. Learners were given the opportunity to conduct their own learning at their own pace at home, while collaborating with their peers and teacher on an online platform for example, through discussion boards. This gave teachers control over what their learners had access to and when they could access this material. During Stage 2, which was referred to as “applying understanding”, an online formative assessment was administered to learners and was submitted at a time designated by the teacher. The learners’ results were used to determine who needed more time and assistance during the live lessons. Stage 3 focused on the application of new understanding. During this stage group and individual tasks were done during live class time. In the context of this study, live classes were done in an in-person context, instead of an online one. Different interactive and dynamic activities were introduced to learners for concept engagement. The more advanced learners, identified based on the formative test results, were tasked to help their peers in understanding the lesson. This stage could be implemented during a synchronous, online lesson. For example, teachers could facilitate virtual laboratory activities, by showing their learners events and processes that would be impossible to show through traditional in-person teaching. An added benefit of this would be that it prevents the violation of bioethical and safety standards, especially when using microorganisms, plants, or animals as test organisms in experiments. Finally Stage 4 was used for the

assessment of learning. Learners' learning was assessed using tests and other tasks. This strategy of implementing the flipped classroom approach, allowed learners the opportunity to develop independence and self-confidence. It also helped them to engage in deep and active learning.

If a teacher's TPACK of synchronous and asynchronous methods is well-developed, then their TPACK of the flipped classroom strategy would be well-developed. In other words, in order to have well-developed TPACK of the flipped classroom strategy, teachers should be able to use digital technology to its full potential in an asynchronous and synchronous context. In an asynchronous context, they should be able to use digital educational technology to its full potential in order to maintain engagement. Whereas, in a synchronous context, teachers should be able to use digital educational technology to maintain social, cognitive and teaching presence online. Since the flipped classroom uses a combination of synchronous and asynchronous methods, digital educational technology should be used to transform teaching and learning in way that would not be possible in a traditional face-to-face context (Koehler & Mishra, 2009).

Hybrid teaching

The flipped classroom can also be used as a hybrid approach that includes the online delivery of content, while face-to-face classes are used for completing practical projects and tasks (Malto et al., 2018). Hybrid teaching includes instruction where content is delivered both in-person and on online platforms (Basilaia & Kvavadze, 2020; Mossavar-Rahmani & Larson-Daugherty, 2007). At least 50% of teaching is transferred to an online platform when using a hybrid approach. Hybrid teaching is used to enrich learners' learning experiences by combining the best features of both online and in-person classes. In a successful hybrid course, learners should be at the centre of the learning community with all other activities designed around them (Mossavar-Rahmani & Larson-Daugherty, 2007).

A hybrid course gives learners the opportunity to access and interact with their teachers both in-person and online, apply learning outcomes both in-person and

online, communicate with their peers both in-person and online, and work as a team both in-person and online. It is important to note that a successful hybrid course requires more complex planning than a traditional face-to-face course. When planning a hybrid course, teachers need to take the following steps into consideration: how technology will be used, how class activities will be divided between face-to-face and online classes, classroom management on online platforms, what role the teacher will play (for example, the role of a facilitator), how assessments will take place on online platforms, and in-person and class participation policies (Mossavar-Rahmani & Larson-Daugherty, 2007).

A benefit of hybrid teaching is that learners can always go back to their online platforms to review work that has been done in the form of lesson recordings and past activities that may be uploaded online. Hybrid teaching also accommodates a variety of learning styles, namely audio, visual and kinaesthetic learners (Mossavar-Rahmani & Larson-Daugherty, 2007).

Hybrid teaching can be used to review videos or other learning resources online that may be too long to review in-person. In-class time can then be used for discussions and hands-on opportunities (Mossavar-Rahmani & Larson-Daugherty, 2007). For Life Sciences specifically, online platforms can be used to review experiment simulations as a pre-learning phase, which can then be followed by in-person laboratory experiments and other practical activities (Sun et al., 2023).

Sun et al. (2023) reported that lecturers in the medical field implemented a hybrid approach in three phases, namely through online preview learning, offline learning and online review learning. During the online preview learning phase, students were given background information and instructional videos on Life Sciences content, laboratory protocols and experiments. After reviewing the background information, the students were given the opportunity to conduct virtual experiments on an online platform and keep a record of their findings. The next phase namely, in-person experiments, helped students to master their practical skills. The lecturers were present to demonstrate and facilitate these in-person practical sessions. After the students conducted their experimental tasks, they uploaded a record of their findings on an online platform. This phase was very important, as a virtual experiment on its own does not give students a real-world experience of what laboratory work is. For example, in-person

experiments and practical tasks give rise to unforeseen problems that need to be solved using problem solving skills. These real-life challenges cannot be simulated on virtual experiments. Finally, an online debrief was done, where students got a chance to present slideshow presentations on their experimental results and to ask questions about any uncertainties they may have had. The lecturer evaluated these presentations and assigned them an online assessment.

In order to have well-developed TPACK of the hybrid teaching strategy, teachers need to be able to effectively use digital educational technology to transform teaching online. In other words, the online component should achieve teaching and learning outcomes that would not be achievable in person for example, through online simulations and applications. In-person lessons should then be facilitated towards increased interaction and engagement, in a way that would not be possible online for example, through hands-on activities. In order to achieve this, teachers would need to carefully plan how teaching will be divided between online and in-person contexts (Koehler & Mishra, 2009; Mossavar-Rahmani & Larson-Daugherty, 2007; Sun et al., 2023).

Representations

Life Sciences teachers are required to teach about complex concepts and relationships. Multiple representations can help learners construct deeper understanding of these complex scientific concepts or system structures, rather than single representations used alone (Ainsworth, 2014; National Research Council, 2012). The use of multiple representations supports complementary processes, for example, accompanying a graph with a table for scientific investigations. Multiple representations can also be used by using familiar representations to help learners understand unfamiliar representations, for example, using a diagram to accompany a description. Finally, the use of multiple representations promotes deeper understanding through abstraction, extension and relations. Abstraction refers to detecting and extracting relevant information from a representation. Extension refers to extending the knowledge learned from one representation to other representations or to new situations. In other words, it means that one is able to make generalisations

from representations. Finally, relations refer to translating between two or more unfamiliar representations (Treagust & Tsui, 2013).

When utilising multiple representations, teachers must consider the design and function of each representation, as well as the cognitive tasks learners will undertake when interacting with the representations (Ainsworth, 2006).

Some examples of representations that Life Sciences teachers can use include visual representations, such as diagrams, natural drawings, graphs, charts, tables, pictures, animations, or objects (Roth et al., 2006; Treagust & Tsui, 2013). As learners compare a variety of visualisations, they are better able to construct deeper understanding (Ainsworth, 2014). Scientists and Life Sciences teachers agree that visualisations are important for learning, practising, and communicating science (Ainsworth & Newton, 2014; Eilam & Gilbert, 2014; Matthewson, 1999). Other representations that can be used for online teaching include digital educational technology like simulations, augmented reality, virtual reality, 3D printers, virtual labs and e-books (Daniel & Woody, 2013; Emine et al., 2018; Treagust & Tsui, 2013).

To add to the body of knowledge above, in this study, Life Sciences pre-service teachers described their perceptions of how their Life Sciences and Life Sciences methodology lecturers used synchronous teaching, asynchronous teaching and the flipped classroom approach. They then described their opinions on how synchronous teaching, the flipped classroom and hybrid teaching should be used to teach Life Sciences on online platforms in schools. They also described the visualisations and online digital educational technology used by their Life Sciences and Life Sciences methodology lecturers, as well as their opinions on the best visualisations and online digital educational technology for teaching Life Sciences on online platforms in schools.

Teachers will have well-developed TPACK of online teaching if they manage to integrate multiple visualisations and digital educational technologies to represent content on online platforms (Koehler & Mishra, 2009).

Advantages and disadvantages of online teaching and learning

As schools transitioned to online teaching for the first time during the COVID-19 pandemic, they faced many challenges. Some of these challenges included limited knowledge on online platforms, limited online resources and tools and technological issues.

Since many teachers would have been exposed to online platforms for the first time during the COVID-19 pandemic, they were very inexperienced when it came to navigating online platforms and the digital educational technology that came with it. This made it difficult for teachers to plan and implement online lessons and online assessments (Ferri et al., 2020; Luz, 2020).

Ajani (2023) conducted a study on the digital divide in South Africa during the COVID-19 pandemic, with a focus on students living in rural areas. Being a developing country, the South African context made it challenging to equitably implement online teaching in all schools across the country. In order to complete the syllabus, many urban schools that were well-resourced managed to successfully shift teaching to online platforms. However, many schools in rural areas that were under-resourced were unsuccessful in moving teaching online. They encountered challenges with regards to infrastructure, power supply, technological devices, connectivity and computational skills. To be more specific, many schools in rural areas lacked teaching and learning infrastructure. Many areas in South Africa, especially rural areas, suffered frequent power outages or did not have any electricity supply. Many teachers and learners that attended rural schools either did not have a laptop or other digital devices or did not have a good quality digital device that would be suitable for online teaching and learning. If teachers and learners had access to these devices, many of them lacked the computational skills to use online platforms to their full potential. Finally, poor connectivity was a challenge in rural areas as well as in urban areas. It was dependent on service providers. This divide in how schools across the country experienced online teaching is referred to as a digital divide (Ajani, 2023; Burgess & Sievertsen, 2020).

This digital divide was also experienced in the Philippines, as reported in a study by Arcueno et al. (2021). In shifting to online teaching for the first time during the COVID-18 pandemic, high school teachers in the Philippines had to make drastic adjustments

on what they taught, how they taught, and what representations they used to facilitate learning. They had limited knowledge of online teaching and limited access to online resources. This made planning content, creating assessments and online teaching more challenging and daunting. In addition to their limited knowledge and limited resources, online teaching was even more disrupted by technological concerns related to connectivity and access.

Despite the challenges of online teaching during the COVID-19 pandemic, online platforms provided a convenient means for communication between teachers and their learners. It also helped learners to develop their time-management and learning skills. They became more disciplined and practices self-paced learning and self-regulated learning (Arcueno et al., 2021). Teachers also benefited from online teaching during the COVID-19 pandemic by getting the opportunity to experiment with online teaching strategies, tools and assessments for the first time. It also gave them a sense of relief, not having to focus on the burdens that comes with in-person teaching. Such as classroom management and various in-person administrative tasks. It gave them the opportunity to focus more on the core role of their teaching profession. Furthermore, the greatest advantage of online teaching during the COVID-19 pandemic was protection from the virus (Alolaywi, 2021).

Chapter 2 provided more detail on the theoretical framework guiding this study namely, the TPACK theoretical framework. It provided details on the teaching strategies (synchronous teaching, asynchronous teaching, the flipped classroom apprach and hybrid teaching) and representations (visualisations and digital educational technology) used on online platforms, as reported by other researchers in the field. This chapter also described the various advantages and disadvantages of online education that were found in a broad context and in a South African context.

Chapter 3: Methodology

This chapter describes the methodology chosen to guide this study. The paradigm guiding this study was interpretivism and is described in terms of its epistemology, ontology, metatheory, methodology and axiology. Furthermore, the research design, sampling method, data collection method and data analysis method are described below. In addition, the quality criteria in terms of the trustworthiness of the study is described, along with the ethical considerations taken while the study was conducted.

3.1. PARADIGM

A paradigm is a cluster of beliefs that dictates what should be studied, how research should be done and how results should be interpreted (Bryman, 2012). Knowing which paradigm a study fits into is important as it determines what questions are worthy of investigation and what processes are required to answer these questions (du Plooy-Cilliers et al., 2021).

The paradigm guiding this study was interpretivism. This allowed the researcher to gain an understanding of the participants' points of view. The aim of this paradigm was simply to interpret the experiences of Life Sciences pre-service teachers of online Life Sciences education. In other words, this study explored the meanings that the Life Sciences pre-service teachers made of their experiences (Ary et al., 2010).

Interpretivism can be described in terms of ontology, epistemology, metatheory, methodology and axiology (Ary et al., 2010; du Plooy-Cilliers et al., 2021; Maree et al., 2016).

Ontological position of interpretivism

Ontology describes how reality is viewed. Interpretivists do not view reality in terms of single, objective truths, but rather as a social construction that is dependent on the meanings that people assign to their experiences and interactions with others. In other

words, reality is subjective (du Plooy-Cilliers et al., 2021). In this study, the Life Sciences pre-service teachers ascribed meaning to their experiences of online education in a university during the COVID-19 pandemic.

Epistemological position of interpretivism

Epistemology deals with the nature of knowledge or the different ways of knowing (du Plooy-Cilliers et al., 2021). The epistemological position of interpretivism describes knowledge as fluid and embedded within a meaning system. This means that facts are not objective but rather more subjective in nature. Facts within this paradigm are dependent on peoples' contexts and their interpretations of their experiences within these contexts.

For this study, knowledge was generated through focus group interviews, whereby Life Sciences pre-service teachers described their experiences of learning Life Sciences and Life Sciences methodology modules on online platforms in university. Based on these experiences, the Life Sciences pre-service teachers described their perceptions of the best teaching strategies and representations that could be used to teach Life Sciences on online platforms in schools. Therefore, the facts generated in this study were dependent on the Life Sciences pre-service teachers' context, namely learning on online platforms during the COVID-19 pandemic. The knowledge generated was further dependent on how they interpreted their experiences of online education namely, which teaching strategies and representations they found to be the most effective, so that they could share their perceptions on how Life Sciences could be taught on online platforms in schools. Since this study was specifically focused on Life Sciences pre-service teachers in a university where lessons were taking place on online platforms during the COVID-19 pandemic, the knowledge generated could not be generalised beyond the context in which the study was. However, the point of this study was not to generalise the findings, but rather to gain an in-depth understanding of Life Sciences pre-service teachers experiences and perceptions of online teaching, with plausible and defensible conclusions (du Plooy-Cilliers et al., 2021).

Metatheoretical position of interpretivism

Metatheory describes the theoretical framework directing a study. Theories in the interpretivist paradigm tell a story. They describe and interpret peoples' experiences within a particular context. The nature of interpretivist research is that it consists of rich and detailed descriptions of phenomena. It aims to reveal the meanings and values that people ascribe to their experiences of phenomena. The information is written as narratives and is therefore subjective and rich in quotes. This gives readers a feel of other peoples' realities. Based on the nature of interpretivist knowledge, selected theories should help guide an understanding of the experiences and lived realities of others through rich and detailed descriptions (du Plooy-Cilliers et al., 2021).

Deductive theorising was used in this study, which means that a theoretical framework was identified and selected before the study was conducted (du Plooy-Cilliers et al., 2021). The theoretical framework guiding this study was the TPACK theory, defined and described in Chapter 2. This theoretical framework helped guide towards an in-depth understanding of how Life Sciences pre-service teachers experienced and perceived the integration of representations such as visualisations and digital educational technology, into teaching strategies such as synchronous teaching, asynchronous teaching, the flipped classroom approach and hybrid teaching (Koehler & Mishra, 2009).

The methodological position of interpretivism

The methodology is a guiding system used to solve problems. Interpretivists view reality as being in a constant state of change and as being dependent on the way in which people experience reality. Since the aim of research in the interpretivist paradigm is to gain an in-depth understanding of multiple realities, a qualitative methodology was chosen to guide this study (du Plooy-Cilliers et al., 2021). In qualitative research the aim is not to control the context and generalise findings. Rather, the aim is to interpret participants subjective meanings, perceptions, views

and opinions by providing thick descriptions of individual lived experiences within real world contexts (Leavy, 2017).

Yin (2016) described five characteristics of qualitative research as follows. Firstly, qualitative research is used to study the meaning of peoples' authentic experiences within the real world, as opposed to controlled environments (du Plooy-Cilliers et al., 2021; Yin, 2016). This study specifically explored Life Sciences pre-service teachers' authentic experiences within an online learning environment at university.

Secondly, qualitative researchers seek to represent the perceptions and values of participants without any predefined notions (du Plooy-Cilliers et al., 2021; Yin, 2016). The aim of this study was to represent the perceptions of Life Sciences pre-service teachers, of representations and teaching strategies used to teach Life Sciences related content on online platforms.

Thirdly, qualitative research takes into account all the conditions within which peoples' lives are rooted, namely social, institutional, cultural and environmental conditions (du Plooy-Cilliers et al., 2021; Yin, 2016). The conditions within which the Life Sciences pre-service teachers' lives were rooted included living through a global pandemic. The global COVID-19 pandemic led to the closure of educational institutions across the world, leading to many institutions opting for online teaching and learning. Subsequently, the Life Sciences pre-service teachers in this study had been learning Life Sciences and Life Sciences methodology modules on online platforms for the entire duration of their studies before data collection took place in the middle of the year, 2022 (ENCA, 2020).

Fourthly, qualitative researchers aim to explain social behaviour through the application of current or emerging theoretical frameworks (du Plooy-Cilliers et al., 2021; Yin, 2016). The TPACK theoretical framework used in this study included the aspect of TK. Having sufficient TK is the ability to recognise that technology can be used to achieve learning outcomes (Koehler & Mishra, 2009). The dimension of TK included online digital educational technology like simulations, augmented reality, virtual reality, virtual labs, e-books and the tools available on online platforms. (Daniel & Woody, 2013; Emine et al., 2018; Treagust & Tsui, 2013). These representations were relevant to online teaching and learning, focused upon in this study.

Finally, triangulation is often used in qualitative research. This means that multiple data collection methods may be used, such as interviews, observations and also using social artefacts (du Plooy-Cilliers et al., 2021; Yin, 2016). This study only made use of one data collection method, namely focus group interviews. However, data saturation was achieved through three focus groups using 14 Life Sciences pre-service teachers in total (Lundborg et al., 1999; Hellström et al., 2003; Sandberg, 1996).

Tracy (2020) further defined three fundamental concepts of qualitative research, namely self-reflexivity, context and thick descriptions. Self-reflexivity refers to how researchers need to take into consideration how their own experiences may influence their interactions with their participants. Researchers' own interpretations of these interactions may lead to data that is subjective and biased. Therefore, it is the responsibility of the researcher to self-examine any prejudice they may have towards their participants and how this could potentially influence data collection. They also need to be careful not to make any spontaneous remarks or reactions throughout the data collection process, such as during interviews (du Plooy-Cilliers et al., 2021; Tracy, 2020). In this study, careful consideration was given to ensure that no spontaneous remarks or reactions were made during the focus group interviews. Having been a PGCE Life Sciences pre-service teacher in 2017, the entire course took place using traditional face-to-face lessons. It was therefore possible not to let personal learning experiences influence the interpretation of the generated data.

The context is the environment within which interactions take place. A qualitative researcher needs to immerse themselves into the data collection process in order to take into account both significant and seemingly insignificant cues. This will allow them to make sense of the contextual environment. Making sense of the contextual environment leads to the formation of thick descriptions (du Plooy-Cilliers et al., 2021; Tracy, 2020).

Thick descriptions are detailed descriptions of the research process, the participants' contributions, the context of the study and the researcher's self-reflection. Unlike in a quantitative study, the researcher does not try to control the context, does not infer any causation and does not aim to generalise findings (du Plooy-Cilliers et al., 2021; Leavy, 2017; Tracy, 2020). Instead, qualitative research emphasises words and their meanings rather than numbers in the collection and analysis of data (du Plooy-Cilliers

et al., 2021). In this study thick descriptions were used to describe how data was collected from Life Sciences pre-service teachers about their experiences and perceptions of online teaching and learning.

Qualitative data collection methods include in-depth interviews, focus group interviews, ethnography and narrative inquiry (du Plooy-Cilliers et al., 2021). For the purposes of this study, data collection took place using 3 focus groups. The context of the first focus group was on an online platform called Microsoft Teams. The context of the second focus group was both on Microsoft Teams and in person in a venue at the university. The third and final focus group took place in person in a venue at the university. The change in context between the 3 focus groups was due to changing levels of lockdown regulations in South Africa in response to the COVID-19 pandemic (South African Government, 2024). Immersion into the data collection process and the varying contexts led to the development of thick descriptions.

Axiological position of interpretivism

Axiology refers to the study of values and value judgement. It gives us an indication of what is valued in a particular paradigm. Interpretivist researchers do not aim to conduct value free research. Instead, discussions are made about how values shape their research, more specifically how the interpretations of the researcher and the participants shape the research outcomes (du Plooy-Cilliers et al., 2021).

This study was not value free. Instead, this study was focused on Life Sciences pre-service teachers' perceptions of teaching Life Sciences content on online platforms, based on their own experiences of learning Life Sciences and Life Sciences methodology modules on online platforms. The Life Sciences pre-service teachers' experiences shaped their perceptions. Furthermore, the researcher's own experiences of online education shaped the interpretation of the Life Sciences pre-service teachers' perceptions of online teaching.

Advantages and disadvantages of interpretivism

One advantage of using the interpretivist paradigm is that it allowed for the exploration of a phenomenon through more than one lens. Interpretivist researchers do not only describe objects, people or events, but they also deeply understand them in social contexts. This study was explored through various lenses (Maree et al., 2016; Pham, 2018; Tuli, 2010; Wellington & Szczerbinski, 2007). More specifically, the phenomenon under study was teaching strategies and representations used to teach Life Sciences content on online platforms. The first lens through which this phenomenon was investigated was through Life Sciences pre-service teachers experiences of learning Life Sciences and Life Sciences methodology modules on online platforms at university. The second lens through which this phenomenon was explored was through the Life Sciences pre-service teachers' perceptions of the best teaching strategies and representations that could be used to teach Life Sciences on online platforms in schools.

Another advantage of interpretivism is that researchers can conduct studies in natural settings, using designs such as grounded theory, ethnography or case studies. This allows more insight into the topic of study (Maree et al., 2016; Pham, 2018; Tuli, 2010; Wellington & Szczerbinski, 2007). This study was conducted in the phenomenon's natural setting, namely either on an online platform used by the university attended by the Life Sciences pre-service teachers or in-person in a venue at the university.

The final advantage was that the data collection method namely, focus group interviews, allowed for the probing of the Life Sciences pre-service teachers' thoughts, values, prejudices, perceptions, views, feelings and perspectives. This led to more insight into their feelings about online teaching (Maree et al., 2016; Pham, 2018; Tuli, 2010; Wellington & Szczerbinski, 2007).

Despite the advantages described above, this paradigm also has some disadvantages. One of these disadvantages is that data collected through methods in the interpretivist paradigm is not generalisable. However, the aim of this study was not to generalise, but rather to gain a deeper understanding of online teaching, specifically of Life Sciences content (Maree et al., 2016; Pham, 2018; Cohen et al., 2011). Another disadvantage of this paradigm is that the ontological position is subjective, rather than

objective. This means that research outcomes are affected by the researcher's own interpretations, belief systems, ways of thinking, cultural preferences and biases (Pham, 2018; Mack, 2010). Care was taken not to allow any personal beliefs influence the outcome of the study. A semi-structured interview schedule was formulated before the focus group interviews were conducted. The semi-structured interview consisted of pre-populated open-ended questions, which were followed by further probing questions during the interview. The probing questions were asked after careful consideration, so that no leading questions were asked. This helped to limit any personal reactions during the focus group interviews.

3.2. RESEARCH DESIGN

This study made use of both a case study design and a phenomenographical design. A case study refers to research on a case set within its real-world context (Maree et al., 2016; Yin, 2009). A case is a phenomenon occurring in a bounded context. Therefore, a case is considered a bounded entity for example a person, an organisation, a behavioural condition, an event or any other social phenomenon (Maree et al., 2016; Miles & Huberman, 1994). In this study the case was a group of 14 Life Sciences pre-service teachers studying towards an education qualification at a university in Gauteng province.

A case study is the preferred design for when "how" and "why" questions are asked (Maree et al., 2016; Yin, 1994). This study set out to answer the following question: "How do Life Sciences pre-service teachers describe their perceptions of best practice for teaching Life Sciences on online platforms in schools, based on their experience of learning Life Sciences and Life Sciences methodology modules on online platforms at university?". It further investigated the following sub-questions: "What teaching strategies and representations did Life Sciences pre-service teachers perceive to be effective when they were learning Life Sciences and Life Sciences methodology modules on online platforms at university?", "What teaching strategies and representations do Life Sciences pre-service teachers perceive to be effective for teaching Life Sciences on online platforms at schools?" and "What are the advantages and disadvantages of teaching Life Sciences on online platforms, as perceived by Life

Sciences pre-service teachers?". During the focus group interviews, these sub-questions were asked along with "why" and "how" questions to develop a more in-depth understanding of the phenomenon.

There are 6 different types of case studies namely, explanatory, exploratory, descriptive, collective, intrinsic and instrumental case studies (Maree et al., 2016). Explanatory case studies explain the causes of phenomena. Exploratory case studies explore and evaluate the outcomes of interventions. Descriptive case studies describe phenomena within their real-world contexts. Collective case studies include more than one case and is used to explore the differences within and between these cases. Intrinsic case studies are used to better understand a case. Finally, instrumental case studies are used when the case is of a secondary interest. Instead, it is used to accomplish something, like provide insight into an issue or help to refine a theory (Maree et al., 2016).

The case study used in this study is a descriptive one. In a descriptive case study, the purpose is to describe a phenomenon in detail within its real-world context. To be more specific, they are used to describe a phenomenon under study, provide information about a phenomenon, describe individuals experiences within a certain context and answer how or what questions (du Plooy-Cilliers, 2021). The main question asked in this study was: "How do Life Sciences pre-service teachers describe their perceptions of best practice for teaching Life Sciences on online platforms in schools, based on their experience of learning Life Sciences and Life Sciences methodology modules on online platforms at university?". The following sub-questions were asked:

- What teaching strategies and representations did Life Sciences pre-service teachers perceive to be effective when they were learning Life Sciences and Life Sciences methodology modules on online platforms at university?
- What teaching strategies and representations do Life Sciences pre-service teachers perceive to be effective for teaching Life Sciences on online platforms at schools?
- What are the advantages and disadvantages of teaching Life Sciences on online platforms, as perceived by Life Sciences pre-service teachers?

This study aimed to describe the phenomenon of online teaching within its real-world context. More specifically, it described the teaching strategies and representations

used to teach Life Sciences content on online platforms, from the perspective of Life Sciences pre-service teachers.

This study also made use of a phenomenographic design, which is a qualitative research design that aims to describe the different ways a group of people experience a phenomenon. The aim of this approach is to study the variation of people's experiences of a particular phenomenon. In other words, the focus of this approach is not the phenomenon itself, which would be described as a phenomenological study, but rather the variation in peoples' ways of experiencing the phenomenon. It offers a second-order perspective (Åkerlind, 2018; Larsson & Holmström, 2007). In relation to this study, the aim was not to understand the phenomenon of Life Sciences online teaching itself, but rather to explore Life Sciences pre-service teachers' experiences and perceptions of the phenomenon of Life Sciences online teaching.

The participants in a phenomenographic study are encouraged to speak freely about their experiences, by giving concrete examples. This avoids superficial descriptions about how things should be or ought to be (Åkerlind, 2018; Larsson & Holmström, 2007). The Life Sciences pre-service teachers were interviewed in 3 focus groups where they each gave descriptive examples of the teaching strategies and representations used by their Life Sciences and Life Sciences methodology lecturers on online platforms. They then gave descriptive examples of the teaching strategies and representations they thought would be best suited to use on online platforms in schools for Life Sciences content. These concrete examples were accompanied by explanations of why and how these teaching strategies and representations were perceived in the ways they were.

3.3. SAMPLING

There are 2 types of sampling methods that can be used in research namely probability and non-probability sampling methods. Probability sampling is used to draw a sample that fits the parameters of a study, is drawn at random from a population, requires little or no influence from the researcher and leads to findings that generalisable. Non-probability sampling on the other hand is used to draw a sample that is also in line with the parameters of the study, where not all the individuals in a population are easily

accessible and where generalisations of results to a broader population are not the goal (du Plooy-Cilliers et al., 2021).

Since the goal of this study was not to generalise findings and the all the individuals in the population were not easily accessible, non-probability sampling was the chosen method. Non-probability sampling is the preferred method for interpretivist studies (du Plooy-Cilliers et al., 2021).

There are 6 types of non-probability sampling methods that can be chosen from namely, accidental sampling, convenience sampling, quota sampling, snowball sampling, volunteer sampling and purposive sampling. Accidental sampling is used to draw a sample that is included purely because they happen to be in the right place at the right time. For example, stopping people in a shopping centre or mall who are willing to participate in the study. Convenience sampling is used to draw a sample of participants that are well known to the researcher or participants that are quick and easy to access. This method may lead to biased data and is therefore mostly used to pre-test data collection instruments. Quota sampling used when the study requires participants to represent different characteristics proportionately. Snowball sampling makes use of referrals to increase a sample size, just like a snowball accumulates more snow to grow in size. Volunteer sampling is used when participants volunteer to participate in a study. An advertisement can be sent out asking for volunteers to participate in a study. Finally, purposive sampling is used to purposefully select a sample that matches a set list of criteria (du Plooy-Cilliers et al., 2021).

Given the nature of this study, the specific non-probability sampling method selected was purposive sampling. In purposive sampling, the research topic and questions are used to carefully draw up a list of characteristics. Then, a sample is selected from the population that has these characteristics, while those that do not are discarded (du Plooy-Cilliers et al., 2021). For this study, Life Sciences pre-service teachers were selected. Additional characteristics included the following: they had to be learning a Life Sciences or Life Sciences methodology module on an online platform at university during the COVID-19 pandemic.

There are 8 different types of purposive sampling methods namely, heterogeneous, homogeneous, typical case, extreme case, critical case, total population, theoretical and expert sampling methods. Heterogeneous sampling is used to select a sample of

participants across a broad range of characteristics that relate to the topic being researched. Homogeneous sampling is used to select participants sharing similar characteristics relating to the topic being researched. Typical case sampling is used to select participants with the assumption that they share similar behaviour patterns, for example selecting participants with the same socioeconomic or educational background. Extreme case sampling is used to select participants with atypical or unusual characteristics. Critical case sampling is used to select participants exhibiting important characteristics during the early stages of research and is then used to determine whether a more in-depth exploration is necessary. Total population sampling is used to select the entire population, if the population meets the criteria and is small enough. Theoretical sampling is used to select research sites, cases, incidents, time periods or data sources. This is used to make comparisons with what has already been studied and is typically used in systematic reviews. Finally, expert sampling is used to select known experts in a particular field of study. It is typically used when sensitive topics are studied (du Plooy-Cilliers et al., 2021).

For the purposes of this study, homogenous sampling was used, because all the participants shared similar traits. More specifically, they were all Life Sciences pre-service teachers studying towards either a B.Ed. degree or PGCE at the same university in Gauteng province. They were all learning Life Sciences and Life Sciences methodology modules on an online platform called Blackboard Collaborate. Permission for the study was granted by the Ethics Committee of the university in Gauteng province, the Registrar and the Dean of the Faculty of Education.

Purposive sampling is a sufficient method for providing an in-depth understanding of the phenomenon being studied. Because of the depth and extent of the information sought in qualitative studies, purposive samples are typically small (Ary et al., 2010). Various studies have shown that approximately 20 participants are usually enough to discover all the different ways of understanding a phenomenon (Lundborg et al., 1999; Hellström et al., 2003; Sandberg, 1996). The sample of this study included 14 Life Sciences pre-service teachers who had experienced learning Life Sciences or Life Sciences methodology on an online platform at university.

Sample size may be influenced by time and availability of participants (Ary et al., 2010). Time is an important consideration as sourcing a sample, contacting them,

collecting data from them, analysing the data and doing a final write up needs to take place within a reasonable timeframe (du Plooy-Cilliers et al., 2021). The participants in this study were contacted and interviewed over a period of 2 months in 2022. The interviews took place at a place and time suitable to the participants. The first focus group took place on an online platform, namely Microsoft Teams. The second focus group took place using a hybrid approach with some students online on Microsoft Teams and some in person in a venue at their university in Gauteng province. Finally, the last focus group took place in person in a venue at their university, as the students were writing an exam on campus that day.

3.4. DATA COLLECTION METHODS AND DATA DOCUMENTATION

Interviews can be conducted in 2 different ways namely in-depth interviews and focus group interviews (du Plooy-Cilliers et al., 2021). In-depth interviews allow the researcher to pose questions to a participant in a one-on-one setting, whereas focus group interviews allow the researcher to pose questions in a group setting.

Focus group interviews were conducted in this study. A focus group is a group interview used to determine the attitudes, behaviours, preferences and dislikes of the participants. In other words, it is used to determine participants experiences of phenomena. It involves the meeting of a small group of participants with the researcher. Participants in the focus group are given the opportunity to express their views and opinions on a particular topic.

When planning focus group interviews it is important to determine whether there are sufficient funds and time available (du Plooy-Cilliers et al., 2021). For this study in particular, there were no major costs involved and there was enough time available to make the focus group interviews worthwhile. Next, it is important to plan how many focus group interviews need to be conducted. Generally, 3-4 sessions are recommended to reach data saturation (du Plooy-Cilliers et al., 2021). In this study, 3 focus group interviews were conducted and were enough to gain valuable insights into the phenomenon of online teaching of Life Sciences content. Finally, the composition of each focus group needs to be determined (du Plooy-Cilliers et al., 2021). In this study, there were a total of 14 Life Sciences pre-service teachers. Eight of these

participants were studying towards a B.Ed. degree in their third year and six of them were studying towards a PGCE. The composition of the first focus group was 6 PGCE Life Sciences pre-service teachers. The composition of the second focus group was 1 PGCE Life Sciences pre-service teacher and 2 B.Ed. Life Sciences pre-service teachers. Finally, the composition of the third focus group was 5 B.Ed. Life Sciences pre-service teachers.

There are 3 ways in which focus groups can be interviewed group (du Plooy-Cilliers et al., 2021). The first way is through informal, conversational interviews. This is used when there are no set, pre-determined questions. Instead, themes are determined which are discussed by the participants with the researcher present. The participants determine the progression of the interview with some guidance. Next, is the general interview approach. It is similar to the conversational interview, except there are now some pre-determined questions attached to each theme. There is still a great deal of freedom given to the participants in determining the progression of the interview. Finally, standardised open-ended interviews are used when there is a set of pre-determined questions asked to all participants in the.

Standardised open-ended interviews were used in this study. More specifically, Semi-structured interviews were used in this study. Pre-determined, open-ended questions were used to facilitate discussion among the participants (du Plooy-Cilliers et al., 2021). Semi-structured interviews involve the formulation of open-ended questions in advance, which are followed by further probing questions during the interview process. This requires the researcher to be very attentive to the participants answers, so that appropriate probing questions are asked that are in line with the phenomenon under study. If a focus interview gets side tracked, probing questions can be used to steer the participants back to the focus of the interview (Maree et al., 2016). Appendix 2 contains the pre-determined questions used in the interview. Probing questions were used to ask them to describe teaching strategies and representations in more detail as well as to further explore relevant, emerging topics. Some of the emerging topics probed were the use of social media for online teaching as well as the advantages and disadvantages of online teaching and learning. When constructing these probing questions, leading questions were not asked, nor were new ideas introduced that had not been expressed by the interviewees. This helped to avoid collecting biased data (Åkerlind & Bowden, 2005).

While other qualitative interviews either focus on the participant or the phenomenon itself, phenomenographic interviews emphasise the relationship between the participant and the phenomenon (Bruce, 1997). Hence, the semi-structured interview questions were carefully constructed, allowing participants to reflect on their experiences (Yates et al., 2012). The semi-structured interview together with probing questions helped to encourage the participants to speak about their experiences of learning Life Sciences and Life Sciences methodology modules on an online platform at university and allowed them the opportunity to give concrete examples about how they thought Life Sciences should be taught on online platforms in schools (Larsson & Holmström, 2007).

There are many advantages of using focus group interviews to collect data. Firstly, debates between participants generated through these interviews can help provide more insight into the topic from different viewpoints (du Plooy-Cilliers et al., 2021). Furthermore, whatever is shared by participants can also be further explored and verified through probing questions. In this study each focus group discussed their opinions on the effectiveness of teaching strategies and representations used to teach Life Sciences on online platforms. They discussed their opinions amongst themselves. They were able to build on and contribute to their peers' contributions. Where relevant, probing questions were asked to gain more insight and understanding, as well as to clarify contradicting responses.

Another advantage of focus groups is that it allows for the collection of data in the form of experiences and perceptions shared by a group of people from similar educational backgrounds with similar experiences (du Plooy-Cilliers et al., 2021). The participants in this study shared similar experiences of online learning, as they all attended the same university during COVID-19.

Finally, this data collection method is very cost effective as it allows for data to be collected from several participants simultaneously. Therefore, it is also more efficient in terms of time, because more data can be collected in a shorter amount of time, as opposed to personal one-on-one interviews (du Plooy-Cilliers et al., 2021). For this study specifically, data collected through focus group interviews was very convenient. The students were contacted and interviewed over 2 months, namely in May and June

in 2022. Since online platforms and venues at the university were used, there was minimal cost involved.

When conducting focus group interviews, it is important to consider the following: the involvement of the researcher, building rapport and the bias of the researcher (du Plooy-Cilliers et al., 2021). When determining the extent to which the researcher should be involved, it needs to be remembered and considered that the participants are human beings with feelings and emotions. Therefore, they need to be respected at all times. They should not be forced to participate or to answer questions that they are uncomfortable with. Building rapport means that care is taken to ensure that the participants feel safe and comfortable with the researcher and their group members. Finally, the researcher needs to remain impartial throughout the focus group interview. They are therefore not allowed to force any opinions or to judge the participants responses.

When conducting the focus group interviews in this study, consideration was taken to ensure that all group members felt safe and comfortable. This was achieved by first explaining what the research study was about and the various themes that would be explored, before the start of each focus group interview. Furthermore, the participants were reminded that the interviews would be recorded but their identities and answers would remain confidential. The contributions made by each group member in each focus group were monitored, so that those who were hesitant to speak were encouraged to share their opinions. and to ensure that everyone had a chance to contribute to the discussions. Care was taken to ensure that no reactions or judgements about the responses were made, and that no leading questions were asked.

3.5. DATA ANALYSIS AND INTERPRETATION

When analysing qualitative data, the nature of qualitative data needs to be considered. Qualitative data is textual, iterative, hermeneutic, subjective, constructed and symbolic (du Plooy-Cilliers, 2021). What is meant by qualitative data being textual, is that qualitative data is usually transcribed into words that are analysed and interpreted. The textual data is important because it helps to convey meaning to the researcher

after they thoroughly and purposefully read it. The data collected in this study was through focus group interviews that were audio recorded. These audio recordings were transcribed into words which were then analysed and interpreted.

Qualitative data is iterative because the analysis and interpretation processes take place in a continuous cycle until conclusions are reached. This helps to identify patterns in the data and to develop a deep and thorough understanding of the meaning of those patterns (du Plooy-Cilliers, 2021). In this study the process of analysis and interpretation took place multiple times until a set list of categories were formed and described.

Qualitative analysis is hermeneutic, which means that it is interpretive du Plooy-Cilliers, 2021. To interpret data, means to understand the meaning of that data. In order to develop an understanding of the meaning of data, movement needs to be made from the general to the specific and then back to the general. This means that data is broken down into codes and categories, which are then put back together in new ways to develop meaning (du Plooy-Cilliers, 2021; Littlejohn et al., 2017). The data was broken down into similar descriptions of teaching strategies and representations used to teach Life Sciences on online platforms. These were then put together into new categories of teaching strategies and representations namely, synchronous teaching, asynchronous teaching, the flipped classroom approach, hybrid teaching, visual representations and digital educational technology representations.

Given the textual, iterative and hermeneutic nature of qualitative data, it can be assumed that there is no absolute truth independent of human interpretation. Rather, human behaviour is described in the context of the person experiencing the phenomenon subjectively. Furthermore, as qualitative data is interpreted by participants and the researcher, meaning is constructed and expressed symbolically depending on the phenomenon and context (du Plooy-Cilliers, 2021).

This study was subjective in nature as it was dependent on Life Sciences pre-service teachers' perceptions and experiences of the phenomenon of online Life Sciences education. The Life Sciences pre-service teachers constructed meaning from their experiences and expressed these symbolically. For example, they were unfamiliar with the terminology used in online teaching, namely synchronous methods, asynchronous

methods and flipped classrooms. Instead, they described these strategies in words that were familiar to them, which were then deconstructed during the analysis process.

Qualitative content analysis was used in this study. Qualitative content analysis is used to explore and identify themes and patterns embedded in textual data. It is the process of reducing data to obtain meaningful interpretations through the identification and description of categories using a systematic coding process. The following 8 steps were followed (du Plooy-Cilliers et al., 2021; Clarke, 2019; Clarke & Braun, 2014; Zhang & Wildemuth, 2009):

1. Preparation and familiarisation of the data
2. Defining the coding units
3. Developing categories
4. Testing the coding scheme
5. Coding and categorising all the data
6. Assessing the coding consistency
7. Drawing conclusions
8. Reporting the findings

Step 1: Preparation and familiarisation of the data

Data was collected through 3 focus group interviews. Each focus group interview was audio recorded. Focus Group 1 took place online on Microsoft Teams and Focus Group 2 took place in a hybrid context, with the online participants joining on Microsoft Teams. This made it possible to use the Microsoft Teams platform to audio record these interviews. Focus Group 3 took place in person therefore, the audio recording of this interview took place on a cell phone.

Once the audio recordings were listened to a few times, they were transcribed into words and read through multiple times. This allowed for a better understanding of the data to be developed.

Memoing was also done to gain a better understanding of the data collected. Memoing is the process of making reflective notes while listening to or reading through the data.

In other words, memos are written to remind oneself of their thoughts and insights while listening to or reading through data (du Plooy-Cilliers, 2021). These memos were helpful in completing the upcoming steps of data analysis.

Step 2: Defining the coding units

A code can be defined as a concise label which is used to uncover and describe something meaningful about the textual data (Clarke & Braun, 2014; du Plooy-Cilliers, 2021). This step refers to the basic coding of the textual data. Individual words, phrases, symbols, sentences or paragraphs were indicated as coding units. It helped to organise the data into manageable portions (du Plooy-Cilliers, 2021).

Some of the codes identified in this study were related to online teaching, such as live online lessons, talk and chalk, chat box, discussion board, pre-recorded lessons, PowerPoint slides, simulations, apps, e-books and many more.

Step 3: Developing categories

Once the coding units were formed, they were then grouped together to form categories. This involved identifying patterns across the coding units and grouping them together (Clarke & Braun, 2014; du Plooy-Cilliers, 2021).

Categories need to have 3 important characteristics namely, they must be exhaustive, mutually exclusive and specific. Exhaustive means that there should be enough categories to accommodate all the data. New categories may emerge after reading through the textual data a few times over. Mutually exclusive means that each category should be distinct and should not overlap with another category. In other words, a coding unit should not fall into more than one category. Finally, categories should be specific, which means that their relevance should be obvious to readers (du Plooy-Cilliers, 2021).

Step 4: Testing the coding scheme

The clarity and consistency of the category definitions were tested on a sample of the textual data. Codes and categories were re-defined when the level of consistency was low.

Additionally, this study used a phenomenographic design. Analysis of phenomenographic data is iterative in nature. This means that identifying and labelling categories took place multiple times, during which the initially formed categories and their descriptions were refined and modified to reach a final set of categories, which best represented the qualitative variations of the phenomenon from the participants' responses (Han & Ellis, 2019).

The initially formed categories were the following, which were still used to help organise data in Table 2:

- Life Sciences pre-service teachers' perceptions of the teaching strategies used by their Life Sciences and Life Sciences methodology lecturers on an online platform at university.
- Life Sciences pre-service teachers' perceptions of the representations used by their Life Sciences and Life Sciences methodology lecturers on an online platform at university.
- Life Sciences pre-service teachers' perspectives of what teaching strategies should be used to teach Life Sciences on online platforms in schools.
- Life Sciences pre-service teachers' perspectives of what representations should be used to teach Life Sciences on online platforms in schools.

The final set of categories formulated were the following:

- Synchronous teaching
- Asynchronous teaching
- Flipped classroom approach
- Hybrid teaching
- Representations
- Advantages and disadvantages of online teaching and learning

Step 5: Coding and categorising all the data

There are 5 types of coding methods namely, line-by-line coding, open coding, axial coding, selective coding and thematic coding (du Plooy-Cilliers et al., 2021). Line-by-line coding is used when the researcher reads through the text, line by line while marking certain key words. Open coding is when the researcher reads the text and writes down key words or concepts on a separate document. Axial coding follows open coding, whereby the key words or concepts are put back together in new ways. In other words, connections are made between the codes. Selective coding refers to selecting codes that correspond with typical or expected behaviour. Finally, thematic coding is used when data is reduced by identifying themes. This form of coding allows the researcher to identify expected themes beforehand, which can then be refined during the actual coding process.

In this study the data was coded using thematic coding and was put into the final set categories listed in Step 4. Synchronous teaching, asynchronous teaching, the flipped classroom approach and hybrid teaching refer to different online teaching strategies that Life Sciences pre-service teachers described. Representations included visualisations and online digital educational technology that Life Sciences pre-service teachers described for online teaching.

Step 6: Assessing the coding consistency

Once all the coding and categorising was complete, the consistency was re-checked. This means that the coding and categorising process was done a second time to establish intercoder reliability (du Plooy-Cilliers, 2021)

Steps 7 and 8: Drawing conclusions and reporting the findings

The final set of categories were interpreted by drawing on the TPACK theoretical framework, previous literature and the researcher's own sense of meaning of the text. Conclusions were reached and reported.

3.6. QUALITY CRITERIA

The point of research in the interpretivist paradigm is not to generalise findings, but rather to develop an in-depth understanding of a particular phenomenon. Therefore, interpretivist researchers do not use numbers as evidence. They use other criteria to determine the trustworthiness of their research. In quantitative research, the terms validity and reliability are used to describe the integrity of the research, but in qualitative research the term trustworthiness is used. Trustworthiness consists of 4 criteria, namely credibility, transferability, dependability and confirmability (Guba & Lincoln, 1994; du Plooy-Cilliers et al., 2021).

Credibility

Credibility is the confidence that can be placed in the truth of the research findings. Credibility establishes whether the research findings represent plausible information collected from the participants and is a correct interpretation of the participants' responses (Korstjens & Moser, 2018).

A strategy used to ensure credibility in this study was prolonged engagement with participants (Korstjens & Moser, 2018). Each focus group interview lasted approximately 30 minutes and was only concluded when the participants had no further information to add, or when data saturation was reached.

Transferability

Transferability refers to the degree to which the results of qualitative research can be transferred to other contexts or settings with other respondents. Transferability was facilitated through thick description, describing not just the experiences of the participants, but their context as well, so that the behaviour and experiences become meaningful to readers (Korstjens & Moser, 2018).

Qualitative research is not generalisable; however, it may be transferable. This means that researchers may use elements of this study to make connections to elements of their studies or experiences (Maree et al., 2016). Being able to generalise is not a primary goal of qualitative research; rather, the primary goal of this study was to understand what was happening in a specific context. The goal was to provide rich and detailed descriptions of the context so that other researchers can make comparisons with their contexts and judge for themselves whether the findings are transferable (Ary et al., 2010).

Dependability and Confirmability

Dependability and confirmability refer to the stability of findings over time. Unlike confirmability, dependability includes the aspect of consistency (Korstjens & Moser, 2018). To achieve dependability, the data analysis process during this study was documented in great detail so that readers can clearly understand how and why certain interpretations were made (Maree et al., 2016).

Confirmability concerns the aspect of neutrality, which was achieved by transparently describing the research steps taken from the start of this study to the development and reporting of the findings. The records of the research path were kept throughout the study (Korstjens & Moser, 2018).

3.7. ETHICAL CONSIDERATIONS

In research, ethics are crucial because they affect various stakeholders for example, participants, the public, research communities, the academic institution of the researcher, policy makers and the researcher themselves. Participants need to be able to trust the researcher and needs to feel safe. The public needs to be able to believe in the value of the research report, as it may directly or indirectly influence them. Other researchers need to be able to rely on the research report as a credible source for future studies. Policy makers may want to use research findings to create new policies or improve on existing policies. Finally, being an ethical researcher influences one's own personal reputation and may impact future employability (du Plooy-Cilliers et al., 2021).

Ethical issues that may affect participants in a study are informed consent, data collection, dealing with sensitive information, providing incentives, avoiding harm, confidentiality versus anonymity, avoiding deception. With regards to informed consent, participants need to be fully informed of the research process and must give their consent before taking part in. They need to be informed about what is expected of them, how their identities will be protected and how the results will be used (du Plooy-Cilliers et al., 2021). In order to ensure informed consent in this study, the Life Sciences pre-service teachers were given informed consent letters (see Appendix 3), signed by the researcher and supervisor. The letters explained the full research process, how their identities would be protected and how the data collected through the focus group interviews would be used. It explained that the study focused on gaining in-depth information on Life Sciences pre-service teachers experiences of learning Life Sciences and Life Sciences methodology modules on online platforms in university and how they thought Life Sciences should be taught on online platforms in schools. It then described the data collection method namely, focus group interviews and what these entailed. The informed consent letters explained that only the researcher and supervisor would have access to the raw data and personal information of the participants. Finally, an explanation of how the data would be used was given. The Life Sciences pre-service teachers were then required to sign the form if they consented to take part in the research study. Participants were allowed voluntary participation and were allowed to withdraw at any point in the research

process. Informed consent forms were filled in by the Life Sciences pre-service teachers as well as the Dean of the Faculty of Education at the university of the participants.

When collecting data from participants, their physical and psychological comfort needs to be prioritised (du Plooy-Cilliers et al., 2021). This can be achieved by informing them of how their personal information will be protected, avoiding asking them embarrassing questions, avoiding wasting their time through poor planning or very long interviews and by carefully considering the physical and social context in which data is collected. This study made use of 3 focus group interviews in 3 different contexts namely, online, a hybrid context and in-person. The participants who attended the interviews online on Microsoft Teams were not pressured to switch on their cameras. They were carefully monitored and made use of the "raised hand" function to ensure that everyone got a chance to contribute to the discussions. Before the start of each of these focus group interviews, the participants were reminded about what the study was about, what was expected from them, how their identities would remain confidential and how the data collected would be used. In other words, they were reminded about the contents of the consent forms they had signed prior to the interview. A venue at the university the students attended was used for the in-person focus group interviews. This ensured that the participants were comfortable as they were in a familiar environment.

The information collected in this study could have been perceived as sensitive to the Life Sciences pre-service teachers involved, as they discussed their perceptions and feelings about the teaching strategies and representations used by their Life Sciences and Life Sciences methodology lecturers on online platforms at their university. The participants were informed through consent forms and verbally about how the data would be used and handled after the interviews were conducted. The students were also told that the focus group interview would be a safe space to discuss their honest opinions about online teaching and learning.

No incentives, such as money or prizes were offered to participants prior to the focus group interviews being held. This decision was made to ensure the integrity of the data collected. If incentives were used, it may have influenced how the participants

answered the questions as they may have felt like they needed to respond in a certain way to please the researcher and get the incentive.

Avoiding harm to participants does not only include physical harm (du Plooy-Cilliers et al., 2021). In focus group interviews harm may include asking questions that may cause one participant to be embarrassed in front of others or some participants may feel that their contributions are less intelligent, relevant or valuable than others. Other examples of harm in education research include causing participants to recall painful memories or creating situations where a participant's future prospects may be harmed. For this study, a semi-structured interview was carefully formulated with no harmful or triggering questions. The focus group interviews were carefully monitored to make sure that everyone got a chance to contribute their honest thoughts without being judged.

Confidentiality and anonymity are two very different terms. Anonymity is undertaken when the names of the participants are not recorded at any stage in the research process. This means that participants names cannot be matched to their responses in any way. Anonymity is usually achieved through survey and questionnaire research designs. Confidentiality on the other hand, is undertaken when only the researcher would be able to match the participants names to their responses. Confidentiality is usually achieved through interviews (du Plooy-Cilliers, 2021). When it came to confidentiality versus anonymity in this study, confidentiality was chosen. This means that only the researcher and supervisor knew they participants personal details and what answers they gave. When transcribing the data, pseudonyms were used to categorise the participants. For example, Focus Group 1 had participants labelled as Participant U, Participant L, Participant M and Participant R on the transcript in Appendix 1. Focus Group 2 had participants labelled as Participant T, Participant J and Participant R. Focus Group 1 took place online while Focus Group 2 took place both online and in person. The context of these focus groups made it easier to keep track of each participant and their responses on the audio recording, as the audio recording was done on the online platform itself namely, on Microsoft Teams. Focus Group 3 took place in person and was audio recorded on a cell phone. This made it more difficult to differentiate between individual participants on the recording. Therefore, these participants were just referred to as "participant" on the transcript in Appendix 1.

Finally, deception was avoided in this study. Deception occurs when participants are given the wrong information about a research study or when they are not given the whole truth about a particular research study. The participants in this study were informed of the research study every step of the way. They were given informed consent forms and were given verbal descriptions of the purpose of the study before data collection started.

Ethics clearance was approved by the Ethics Committee of the Faculty of Education at the university in Gauteng province before any research was conducted. The ethics principles of the University were adhered to.

Chapter 3 described the methodology chosen to guide this study in detail. The paradigm namely, interpretivism was described in terms of its ontology, epistemology, metatheory, methodology and axiology. Furthermore, the research design, sampling method, data collection method, analysis method, quality criteria and the ethical considerations were described in detail. Reasons for the chosen methods were described, along with the advantages and possible limitations of these methods.

Chapter 4: Results

Chapter 4 provides a description of the participants in this study namely, the Life Sciences pre-service teachers and all of their characteristics. This chapter also gives a presentation of the results collected through the focus group interviews. It describes what the Life Sciences pre-service teachers said about online teaching strategies (synchronous teaching, asynchronous teaching, the flipped classroom approach and hybrid teaching) and online representations (visualisations and digital educational technology)

4.1. DESCRIPTION OF PARTICIPANTS

The participants in this study included 14 Life Sciences pre-service teachers studying towards a B.Ed. degree in their third year or a PGCE as described in Table 1 below. Of the 14 Life Sciences pre-service teachers, 6 attended Focus Group 1, 3 attended Focus Group 2 and 5 attended Focus Group 3. The table also indicates whether the interview with the participant was online or in-person. In Focus Group 1, all participants attended online. In Focus Group 2, 2 participants attended online and 1 attended in-person. Finally, in Focus Group 3, all participants attended in person.

Table 1: Description of participants

Focus group 1						
Participant	1	2	3	4	5	6
Qualification	PGCE	PGCE	PGCE	PGCE	PGCE	PGCE
Online/in-person	Online	Online	Online	Online	Online	Online
Focus group 2						
Participant	1	2	3			
Qualification	PGCE	B.Ed. third-year	B.Ed. third-year			
Online/in-person	Online	In-person	Online			
Focus group 3						
Participant	1	2	3	4	5	
Qualification	B.Ed. third-year	B.Ed. third-year	B.Ed. third-year	B.Ed. third-year	B.Ed. third-year	
Online/in-person	In-person	In-person	In-person	In-person	In-person	

4.2. RESULTS

Three focus group interviews were conducted. Focus Group 1 took place online on Microsoft Teams. Focus Group 2 took place using a hybrid approach with students online on Microsoft Teams and some in-person in a venue at their university. Focus Group 3 took place in-person in a venue at their university.

The Life Sciences pre-service teachers reflected upon their experiences learning Life Sciences and Life Sciences methodology modules at university.

Synchronous teaching

Synchronous teaching was described by all three focus groups. It is an online teaching strategy whereby teaching takes place in real-time. The teacher or lecturer usually

schedules these lessons in advance and there is a pre-set time for everyone to log in and join a live session (Basilaia & Kvavadze, 2020; Shi & Morrow, 2006). The Life Sciences pre-service teachers reported using the online platform 'Blackboard Collaborate' for their synchronous lessons. Group 1 called this approach "talk and chalk", while Group 2 called it "teach and tell".

Students reported that much of the teaching that occurred during the synchronous sessions could be described as "talk and chalk" presentations.

The "talk and chalk" method is one way of doing synchronous teaching. It is a teaching strategy whereby teachers deliver content to learners in a verbal manner (Jumanto et al., 2018). The learners are not required to engage or interact during these lessons. Teachers provide the learners with all the information they need, so that learners do not have to look for information on their own. In other words, the learners are not required to practice self-directed learning. The learners are only expected to learn from the material they receive from their teachers. The general progression of these lessons includes the teacher speaking at the beginning of the lesson, then explaining the material by giving examples and going through questions and answers. The learners are only required to listen and make notes. There is no discovery element, which makes this strategy very teacher centred. "Talk and chalk" is a method that emphasises the verbal delivery of information from the teacher to the learners. If teachers use an active element, such as giving learners the opportunity to ask questions and to complete activities, it helps learners to master the content being taught.

A PGCE Life Sciences pre-service teacher in Group 1 described the "talk and chalk" strategy as follows: *"It was mainly just like a lot of "talk and chalk" where she would just present the content and then we would have to listen. Yes, just listen and then at the end, we'd maybe just ask a few questions, if maybe we don't understand something and then we just end the session there".*

A third-year B.Ed. Life Sciences pre-service teacher in Group 2 described the "teach and tell" strategy as follows: "*They told us the content and how it could be asked and then they let us ask questions if we had any, but there was no use of questioning tactics. It was still possible for me to learn. I wasn't able to get like a master understanding, but I had a basic understanding of the content. I just think it would have*

been a lot more beneficial if lecturers tried to engage with us during lectures". This strategy was compared to watching a YouTube video. A PGCE Life Sciences pre-service teacher in Group 2 suggested the following: *"Lecturers should allow us to engage during online lessons, not just tell us what they expect from us. They should allow us to engage in class, ask questions"*. The PGCE Life Sciences pre-service teacher did say that these synchronous lessons were only beneficial when their Life Sciences methodology lecturer discussed examples of how to handle different scenarios that they may encounter as Life Sciences teachers in the future.

A third-year Life Sciences pre-service teacher in Focus Group 3 described the synchronous teaching strategy that their Life Sciences lecturer used as follows: *"It's just them talking to themselves, and then some questions. But some lecturers even ignore the questions. They just go through the slides. They are reading the slides, they don't teach. That was not good"*. This was further supported by another third-year Life Sciences pre-service teacher in the same focus group who shared their experience as follows: *"Then you have to write everything down. You're more focused on writing down the precisity (preciseness) of what the lecturer is saying than actually taking it in and understanding the concept".* The only perceived benefit of this teaching strategy from Group 3 was that it helped them to develop their time-management and research skills, which are important skills in their future career as Life Sciences teachers. They suggested that this teaching strategy could have been more beneficial if it was more interactive and engaging.

For teaching Life Sciences on online platforms in schools synchronously, all focus groups suggested that online platforms be used to their full potential to enhance interaction and engagement.

The PGCE Life Sciences pre-service teachers in Focus Group 1 suggested the use of the chat function, breakout groups and the poll function. One of the participants in this focus group suggested that the chat box be monitored by the Life Sciences teacher regularly to ensure interaction, because their lecturers sometimes forgot to do this. The breakout room was described as follows: *"You go there, you discuss this certain question amongst yourselves and then maybe you come back now, then you present the knowledge that you shared".* Group work using breakout rooms was perceived as an important tool that can be used to teach Life Sciences online because learners

learn best when they have interaction with their peers. The collaborative learning helped to reduce isolation caused by the COVID-19 pandemic and helped students to develop and maintain social bonds with their peers. Furthermore, it gave students the option of seeking help from their peers instead of their lecturers, which some of the students found more comfortable.

The poll function was described as follows: *"On Blackboard, I know they've got a poll function to take a quick vote from the class. I don't think that's used enough. If we are in-person, we would be asking questions to the class, trying to get feedback to keep them engaged, and you can do that on Blackboard"*.

Group 2 also discussed how online platforms should be used to their full potential in schools to promote interaction and engagement. One of the third-year Life Sciences pre-service teachers in Group 2 described this as follows: *"A lot of what we can do on online platforms emulates what we can do in normal school. For example, instead of having them write on the chalk board you can say type the answer on the chat function, or you can even like call them to the front and ask a specific student please write what you think on the slide itself. There's also breakout rooms you can make use of".* A third-year Life Sciences pre-service teacher in Group 3 also suggested breakout rooms as follows: *"I believe I learn best when I am with my peers than when I'm with the teacher. When the teacher is explaining, I can get some information, but with my peers I feel like I can relate"*. Another third-year B.Ed. student further explained that it is the responsibility of the Life Sciences teacher to research the online platform they are using: *"Researching the platform, finding out what things you can do, because a lot of people just think it's like virtual classrooms, but there are things you can do on Blackboard that you can't do in a normal classroom".*

The participants in Group 3 also discussed a drawing or writing tool that their Life Sciences and Life Sciences methodology lecturers used to draw or write on a white screen, which is similar to a white or black board in a traditional classroom. They described the tool as follows: "It's just a laser thing, that as they present the PowerPoint, they just put the laser on, then they can draw".

Asynchronous teaching

Asynchronous teaching, unlike synchronous teaching refers to lessons that do not take place in real-time. Instead, learning material is provided to students on an online platform that they can work through in their own time, for example pre-recorded lessons and online assessments. Support is still available through the online platform, for example through discussion boards (Basilaia & Kvavadze, 2020; Biswas & Maiti, 2022; Reinholz et al., 2020; Skylar, 2009). Only the PGCE Life Sciences pre-service teachers in Groups 1 and 2 reported their Life Sciences methodology lecturers using an asynchronous approach. A participant in Group 1 said that their Life Sciences methodology lecturer uploaded pre-recorded lessons for them to watch and work through in their own time. This strategy was perceived as beneficial. The benefits were described as follows: *"I think the good thing about it is you don't have to miss class. Like if it was contact classes there were going to be possibilities for you to miss class, but then if it's recorded, then you watch it at your own time".*

However, a participant in Focus Group 2 perceived this asynchronous teaching strategy as ineffective. The student expressed their preference for live, interactive online lessons as follows: *"At the beginning when we had interactive classes, it was very effective because I could engage with the lecturer, but then right now, because she uses more asynchronous classes, I tend to be lazy to watch the recording".* It was then suggested that these asynchronous recorded lectures should only be about 20 minutes long so that students do not lose attention.

Flipped classroom approach

Synchronous and asynchronous teaching strategies may be combined into a flipped classroom approach. The flipped classroom is a teaching strategy whereby learning material is given to students to work through in their own time. This is then supplemented with live, online sessions to discuss the learning that took place (Marina & Ridlo, 2021).

Focus Group 2 described how their lecturers used a flipped classroom approach, even though they were not familiar with the term. One of the third-year B.Ed. Life Sciences pre-service teachers in Focus Group 2 expressed the importance of engagement with content in Life Sciences by stating the following: *"In Life Sciences you have to, like, engage the content to get it, because it's very hard"*. The participant believed that this was achieved by one of their Life Sciences and Life Sciences methodology lecturers who used a strategy described as follows: *"He was giving us, like, a question, that okay, we participate on, and we find information on, and then we just discuss it on a discussion board"*. They were given resources such as PowerPoint slides and lesson recordings to work through on their own and discuss on discussion boards, before discussing them in synchronous online classes. This strategy was perceived as effective by the participant. However, even though the flipped classroom was perceived as effective, the participant believed that students needed to be willing to learn in order to benefit from it.

Focus Groups 1 and 3 suggested a flipped classroom approach for teaching Life Sciences on online platforms in schools. A PGCE Life Sciences pre-service teacher in Focus Group 1 suggested the following: *"So, you do the background during class online and then you just let the children do it themselves practically themselves. They maybe, they would come back with the results or whatever they found then we could discuss it over class online again".* This basically means that content would be discussed online before allowing learners the opportunity to do a practical task on their own. Learners and Life Sciences teachers would then re-join the online lesson to discuss their findings. This would give learners the opportunity to engage with content in-person, using a hands-on approach. A third-year Life Sciences pre-service teacher in Focus Group 3 suggested formative assessments be assigned as an independent learning component of the flipped classroom, for example, online quizzes such as Quizlet and Kahoot. They were perceived as beneficial for Life Sciences teachers because they are self-marked and provide important feedback about learners' progress and understanding.

Hybrid teaching

Hybrid teaching takes place both in-person and on online platforms. Teaching using this method requires careful planning on how to divide content between an in-person and online context (Basilaia & Kvavadze, 2020; Mossavar-Rahmani & Larson-Daugherty, 2007).

When asked whether Life Sciences could be taught online, both Groups 1 and 2 said 'yes'. However, everyone in Focus Group 3 agreed that Life Sciences could not be taught online completely. Some participants in that focus group suggested a hybrid approach so that there would be some face-to-face interaction. One of the Life Sciences pre-service teachers in the same focus group said the following: *"Life Sciences is very practical. You want to touch the stuff, you want to see it, and online is not that Interactive. So, I think it won't be that successful, only online".* They went on to further explain why a hybrid approach would be most beneficial, as follows: *"I think the only time Life Sciences will only work online is when you just give learners group work or assignments. In that way, online, it will work. But, when you have to introduce a topic, you need to be face-to-face, in contact with the learners. See where they are struggling. Make sure they understand".*

Focus Group 3 preferred face-to-face or hybrid teaching, because they had just been given the opportunity to go back to university to write exams in-person after almost three years of learning online. They were meeting their lecturers and peers for the first time since they started their B.Ed. in 2020. They also said that the only way in which online learning could be beneficial is if Life Sciences teachers ask their learners to switch their cameras on during online lessons, to help with interaction and to read facial expressions to see whether learners understand what is being taught.

Representations

All focus groups described some visual representations used by their Life Sciences and Life Sciences methodology lecturers. These included PowerPoint presentations,

pictures and other reading material. Visual representations are also called visualisations. They include visually stimulating resources used to portray theoretical and conceptual content. More than one visualisation is usually used at once to help learners make comparisons for deeper understanding of content (Ainsworth, 2014; Eilam & Gilbert, 2014; Matthewson, 1999; Roth et al., 2006; Treagust & Tsui, 2013).

One of the PGCE Life Sciences pre-service teachers in Group 1 perceived these representations as effective, but not exclusive to online teaching. The student said the following: *"I'll say, they're pretty effective, but it's not exclusive to online learning. The same things would've been used in a slide show in-person".*

A third-year Life Sciences pre-service teacher in Group 3 found PowerPoint slides as a representation to be ineffective, and said: *"Firstly the slides are just summaries. So basically, they are just highlighting the important concepts. The rest of the work, you just have to do it on your own. So, basically you are teaching yourself the subject"*. They added that PowerPoints could be made better by making them more detailed, with the inclusion of embedded videos and recorded voice-overs.

Focus Groups 2 and 3 described how their Life Sciences and other Science lecturers used digital educational technology. Digital educational technology includes online resources that helps to provide more engagement (Daniel & Woody, 2013; Emine et al., 2018; Haleem et al., 2022; Treagust & Tsui, 2013). The digital educational technology discussed in this study includes online simulations, online applications, experimentation software, e-books, YouTube videos and Demo videos.

The third-year Life Sciences pre-service teachers in Focus Group 2 recalled that one of their Science lecturers made use of an online simulation to play with electric circuits. This online simulation is called Physics Education Technology (PhET) and was not used specifically for Life Sciences content. One of the third-year Life Sciences pre-service teachers further suggested that their Life Sciences and Life Sciences methodology lecturers could have used experimenting software specifically suited to Life Sciences content.

The third-year Life Sciences pre-service teachers in Focus Group 3 recalled using online applications in their Life Sciences lessons at university. They recalled using applications called OWL (Online Web Learning) and Organs. Organs was very interesting and was described as follows: "*It shows you internal organs in 3D. Yeah,*

internal organs and you can zoom in and out and move around, because that makes it exciting." They also recalled their Genetics lecturer assigning the use of an online interactive textbook with embedded quizzes for Genetics content. They went on to suggest that more applications and online educational games would have been beneficial to them when learning Life Sciences online.

Focus Groups 2 and 3 also described a visual and digital representation that their lecturers used, namely YouTube and Demo videos.

A PGCE Life Sciences pre-service teacher in Focus Group 2 recalled their Life Sciences methodology lecturer recording a Demo video for them. The representation was described as follows: *"She recorded a video and uploaded it on ClickUp and then we went there and watched the video and then designed our practical examination"*. The participant explained that the Demo video explained how the students should do an assessment that required them to design a practical examination with five stations. This representation was perceived as very effective in helping the students prepare for their assessment. A participant in Focus Group 2 felt that their Life Sciences and Life Sciences methodology lecturers could have included more Demo videos on scientific investigations and experiments. One of the third-year Life Sciences pre-service teachers in the same focus group further suggested the following: *"I think they should just make videos of them making the experiment, even if it's a simulation".* Another third-year Life Sciences pre-service teacher expressed the importance of scientific investigations and practical activities by stating the following: *it's a Science subject and it has to have investigations, demonstrations, practical work, experiments and everything".*

For teaching Life Sciences on online platforms in schools, all focus groups suggested the use of multiple representations. This use of multiple representations to represent Life Sciences content can help with a challenge pointed out by a third-year B.Ed. Life Sciences pre-service teacher namely, that there are many common terms in different science-related subjects that may cause misconceptions among learners.

Most of the Life Sciences pre-service teachers suggested the use of PowerPoint slides, pictures, videos and experimentation software, for example, online simulations and applications. Experimentation software was perceived as very important and necessary when teaching Life Sciences on online platforms. One of the PGCE pre-

service teachers in Group 1 recalled going on their teaching practical at a school during the COVID-19 pandemic, and described a conversation they had with one of the Life Sciences learners as follows: *"They want to be actively involved in doing an experiment or watching a simulation of how the experiment would have happened in real life situations".* Another participant in the same focus group also pointed out the importance of including some sort of experimentation in preparing learners for university and careers in science: *"If we don't teach learners how to become, practice to become scientists, then we just throw them into the university space where they will actually be performing these experiments and stuff like that, there'll be a gap".* The third-year Life Sciences pre-service teachers in Group 3 suggested that schools need to invest in Life Science-related applications, and not just rely on the free ones: "*I think if a school goes online, the school has to be willing to invest in some applications that they can give to the students. Because, we had an assignment that we had to find free apps and free something, like to do a hybrid learning approach. But I think if you're a school that is a hybrid or totally online, then they need to invest in that, because they're not paying for paper and textbooks and things like that. So, they can buy Biology apps or something like that".* Those applications that are paid for were perceived as having better quality than the free ones.

Another way of representing experiments and practical content in Life Sciences is the use of videos, including YouTube videos. One of the third-year Life Sciences pre-service teachers in Group 2 recalled using a video to represent how air moves through lungs during their teaching practical as follows: *"I showed them how you attach lungs to the machine and then it pumps. So, that's nice stuff you can use. And that's making it visual".* Another third-year Life Sciences pre-service teacher added: *"Yeah, you have to replace the practical experience that you would have had in class. With a visual one. With a visual one that's equally as efficient, effective or even more so".* Another third-year Life Sciences pre-service teacher in Group 2 suggested YouTube videos on science-related channels such as the Amoeba Sisters and Crash Course after class. Another participant in the same focus group took it a step further and suggested that learners may be asked to perform experiments themselves in the form of videos. This would help with engagement as well as with the development of scientific skills.

Multiple representations of Life Sciences content can be presented on online platforms like Blackboard Collaborate, which was used by the participants in this study. Other

applications suggested were Discord, One Note, Google Classroom, District 4 and social media.

Discord was suggested by one of the third-year Life Sciences pre-service teachers in Group 2. The participant described Discord as a good, free application that can be used to represent an entire online learning environment outside of the online classroom.

One Note was suggested by a PGCE Life Sciences pre-service teacher Group 1. It was proposed as a platform for uploading videos and assessments. It allows teachers to set a specific amount of time for the uploaded videos to be viewed by learners. It was then suggested by the same PGCE Life Sciences pre-service teacher that uploading videos and assessments on One Note be used in conjunction with the flipped classroom teaching strategy described above, by scheduling at least one live online lesson a week to address questions that learners may have.

The third-year Life Sciences pre-service teachers in Group 3 then suggested the use of Google Classroom and District 4 for representing content.

Focus Group 2 suggested the use of social media for representing Life Sciences content in schools. One of the third-year Life Sciences pre-service teachers justified the representation of Life Sciences content on social media platforms by stating the following: *"Learners stay online for social gatherings, for social meetings with their friends. Why can't they stay on social media to study or to do something academic related?"* In contrast, another third-year Life Sciences pre-service teacher believed that the use of social media for representing Life Sciences content would be a negative factor, as learners use social media to get away from academic content. The participant further justified their answer by using the following example: *"If I was scrolling through Instagram after studying and then I see my education psychology slide, 'm going to leave, and then I'm going to go into the classroom slides".* This participant then went on to discuss the possibility of using social media platforms that are not really being used for socialising in today's world, for example, Facebook. A PGCE Life Sciences pre-service teacher in the same hybrid focus group interview added that social media should rather be used for communication and for sharing of content over WhatsApp.

Advantages and disadvantages of online teaching and learning

Participants in Groups 1 and 3 perceived some disadvantages of online education for teachers. A PGCE Life Sciences pre-service teacher Group 1 believed that older teachers would never have used online digital educational technology and would therefore put their learners at a disadvantage. A third-year Life Sciences pre-service teacher in Group 3 said that teaching online could be challenging for all teachers because they would not be able to determine whether their learners need support based on facial expressions and body language.

A disadvantage discussed by all focus groups was the digital divide in South Africa between well-resourced schools that have the privilege of teaching online and under-resourced schools that lack the digital educational technology required to teach online. A PGCE Life Sciences pre-service teacher in Group 1 expressed the following: *"I don't think it (online education) caters for students that are in, you know, the townships and stuff like this. I think it's still a pretty big divider in the society, so I think I don't know how we would, we could, like try and make sure that these learners are also involved or like included. But I still think it's quite like an alienation tool".* Another PGCE Life Sciences pre-service teacher in the same focus group added the following: *"It won't work if it's like a rural area, because none of, if not most of those students don't have access to computers, internet, Wi-Fi, all of that".*

However, a third-year Life Sciences pre-service teacher in Group 2 said that a number of schools have become more technological over the years, especially since the start of the COVID-19 pandemic and subsequently, schools have moved towards using online platforms. The student said the following in this regard: *"I think it's important that we start in learning how to integrate technology where we can. However, we must, the curriculum must not be changed because until every classroom in this country has the same technology, we can't really make this the standard. This is something that's beneficial to those who can have it. But the curriculum must still be designed for those who can't have it".*

Another disadvantage of online education discussed by a PGCE Life Sciences pre-service teacher in Group 1 is the potential language barrier. This was perceived as a potential barrier because teachers would not be able to assist learners in person who

do not speak English as a home language. However, another participant in the same focus group said that online education may actually be beneficial to learners who do not speak English as a home language, because they would have access to lesson recordings and watch them in their own time and even pause them if necessary.

Another perceived disadvantage to online education in Life Sciences specifically was that learners would not be able to do practical activities in-person. A PGCE Life Sciences pre-service teacher in Group 1 shared the following thoughts on organ dissections, which is a big component of Life Sciences: *"I feel like those student needs to touch that heart for them to have a feel and to be in touch with the content and to understand more of it. So, I feel like with practicals, it can be at a disadvantage in a way".*

The Life Sciences pre-service teachers also discussed the advantages of teaching Life Sciences on online platforms. One of the advantages mentioned by a third-year Life Sciences pre-service teacher in Group 2 was that teaching online allows teachers to teach more information in a shorter time. Another advantage mentioned by a participant in the same focus group is that teaching online allows more flexibility for both teachers and learners.

Table 2 below summarises the teaching strategies and representations described by Life Sciences pre-service teachers. Specifically, it shows the teaching strategies and representations they described their Life Sciences and Life Sciences methodology lecturers using on online platforms at university, and the suggested teaching strategies and representations for teaching Life Sciences on online platforms in schools.

Table 2: Life Sciences pre-service teachers' perceptions of teaching strategies used by their Life Sciences and Life Sciences methodology lecturers on online platforms at university, and their perceptions of the teaching strategies and representations that should be used on online platforms in schools.

Life Sciences pre-service teachers' perceptions of the teaching strategies used by their Life Sciences and Life Sciences methodology lecturers on an online platform at university.	**Life Sciences pre-service teachers' perceptions of the representations used by their Life Sciences and Life Sciences methodology lecturers on an online platform at university.**	**Life Sciences pre-service teachers' perspectives of what teaching strategies should be used to teach Life Sciences on online platforms in schools.**	**Life Sciences pre-service teachers' perspectives of what representations should be used to teach Life Sciences on online platforms in schools.**
• Synchronous teaching • Asynchronous teaching • Flipped classroom approach	• PowerPoint slides • Pictures • Reading material • Online simulations and applications • Genetics e-book • YouTube videos • Demo videos	• Synchronous teaching • Flipped classroom approach • Hybrid teaching	• PowerPoint slides • Pictures • YouTube videos • Demo videos • Experimentation software (Online simulations and applications)

Table 3 below shows what Life Sciences pre-service teachers perceived to be the advantages and disadvantages of teaching and learning Life Sciences on online platforms.

Table 3: The perceived advantages and disadvantages of teaching and learning Life Sciences on online platforms

Perceived advantages of teaching and learning Life Sciences online	Perceived disadvantages of teaching and learning Life Sciences online
• Developed time-management skills • Developed research skills • Increased flexibility • Recorded lessons	• Unfamiliarity with online platforms and associated digital educational technology • Digital divide between well-resourced and under-resourced schools • Communication and language barriers • Missing out on a hands-on approach in Life Sciences

The tables above summarise how Life Sciences pre-service teachers described their perceptions of best practice for teaching Life Sciences on online platforms in schools, based on their experiences of learning Life Sciences on online platforms at university. They specifically describe the teaching strategies and representations Life Sciences pre-service teachers perceived to be effective when they were learning Life Sciences on online platforms at university, and the teaching strategies and representations they perceived to be effective for teaching Life Sciences on online platforms at schools. Furthermore, the advantages and disadvantages of teaching Life Sciences on online platforms, as perceived by Life Sciences pre-service teachers, were described.

Chapter 4 showed the data collected through focus group interviews, during which Life Sciences pre-service teachers described their experiences of learning Life Sciences and Life Sciences methodology lecturers on an online platform called Blackboard Collaborate. Based on their experiences, 3 teaching strategies were identified and described namely, synchronous teaching, asynchronous teaching and the flipped classroom approach. The Life Sciences pre-service teachers also reflected upon their experiences of online Life Sciences education and suggested that the best teaching strategies for teaching Life Sciences on online platforms in schools are synchronous teaching (with social, cognitive and teaching presence), the flipped classroom approach and hybrid teaching. Hybrid teaching was suggested, because the students in this study felt isolated learning on online platforms during the COVID-19 pandemic. Further to teaching strategies used to teach Life Sciences on online platforms, the Life Sciences pre-service teachers also discussed their experiences and perceptions of

the representations used for online Life Sciences education. These representations included various visualisations such as PowerPoint slides, pictures and videos. They also included digital educational technology such as online simulations and applications. An emerging topic that arose after data collection was the advantages and disadvantages of online teaching and learning. The Life Sciences pre-service teachers reflected on the experiences and described how they appreciated the skills that online education taught them, but also the challenges they experienced with navigating online platforms. They also reflected upon the digital divide in the country during the COVID-19 pandemic.

Chapter 5: Discussion

Chapter 5 provides a comprehensive discussion on the findings in this study in relation to the literature and the TPACK theoretical framework in Chapter 2. The findings are divided into the following themes: synchronous teaching, asynchronous teaching, the flipped classroom approach, hybrid teaching and representations. Furthermore, the limitations, implications and conclusions of the study are discussed.

5.1. DISCUSSION

Synchronous teaching

Life Sciences pre-service teachers in all three focus groups in this study reported their Life Sciences and Life Sciences methodology lecturers using the Blackboard Collaborate online platform for synchronous teaching during the COVID-19 pandemic. Synchronous teaching is done in real-time with a live teacher. There is a pre-set time to log in to an online platform and learners can communicate directly with the teacher and their peers (Basilaia & Kvavadze, 2020; Shi & Morrow, 2006).

Unfortunately, the Life Sciences pre-service teachers perceived these synchronous lessons as lacking in interaction and engagement. In other words, they implied that these lessons were lacking in social presence, cognitive presence, and teaching presence (Reinholz et al., 2020). Social presence refers to social connection within the online learning environment (Kozan & Richardson, 2014). Life Sciences pre-service teachers in this study were very rarely given an opportunity to interact with their lecturers and ask questions. Cognitive presence involves the teacher creating opportunities for their learners to explore, reflect and construct meaning (Garrison, 2007). The Life Sciences pre-service teachers were not given any opportunities to engage with content during these lessons. It was compared to watching a YouTube video. Finally, teaching presence focuses on the ways that teachers make meaningful learning opportunities available to learners. This involves using a variety of different

technologies to provide different opportunities for participation (Rienties et al., 2013). The Life Sciences pre-service teachers felt that they were not involved in these synchronous lessons and were not given any opportunities to participate in these lessons.

Social, cognitive and teaching presence are three very critical considerations needed for creating productive synchronous online learning environments (Reinholz et al., 2020). This supports the Life Sciences pre-service teachers' negative perceptions of the synchronous teaching strategy used by their Life Sciences and Life Sciences methodology lecturers, as these were lacking in social, cognitive and teaching presence.

This shows that the problem was not the synchronous teaching strategy itself, but rather the way in which synchronous lessons were delivered. They were delivered using a "talk and chalk" method, which is very teacher centred. This means that the teacher usually delivers content verbally, without giving learners enough the opportunities to engage or interact (Jumanto et al., 2018).

Teachers have sufficient TPACK on an online platform if they manage to present content in an interactive and engaging manner (Koehler & Mishra, 2009). The Life Sciences pre-service teachers perceived their Life Sciences and Life Sciences methodology lecturers' and Life Sciences methodology lecturers' TPACK as underdeveloped when using only the synchronous teaching approach, as they did not manage to present content in an interactive and engaging manner online.

Social, cognitive and teaching presence are interrelated and must be considered together (Garrison, 2007). Strategies that can be used to maintain social, cognitive and teaching presence include re-establishing classroom norms, using student names, using breakout rooms, chat-based participation, polling software, creating an inclusive curriculum and reducing content to maintain rigour (Reinholz et al., 2020). For synchronous teaching in schools, all focus groups suggested that Life Sciences teachers use breakout rooms, chat-based participation and polling software in order to enhance interaction and engagement, which would in turn enhance social, cognitive and teaching presence.

The Life Sciences pre-service teachers displayed well-established TPACK as they managed to suggest how online Life Sciences teachers could present content in an

interactive and engaging manner in schools during synchronous lessons. In other words, they took social, cognitive and teaching presence into consideration when suggesting teaching strategies and representations that can be used to teach Life Sciences on online platforms in schools.

Asynchronous teaching

Asynchronous teaching refers to lessons that do not take place in real-time. Instead, learners are provided with learning material on a regular basis to work through on their own, for example, pre-recorded lessons or at-home assignments. Teachers then provide regular support through online communication platforms, for example, via discussion boards, email or WhatsApp (Basilaia & Kvavadze, 2020; Biswas & Maiti, 2022; Reinholz et al., 2020; Skylar, 2009). The Life Sciences pre-service teachers in Groups 1 and 2 reported one of their Life Sciences methodology lecturers using an asynchronous approach, whereby pre-recorded lessons would be shared for students to watch and work through in their own time.

To be effective in promoting learning, when planning and creating pre-recorded lessons, teachers need to ensure that information is presented in short, learner-paced segments; with conversational speech, instead of just using on-screen text; without extraneous information; with high-quality pictures and animation; and with cues that highlight important information (Choe et al., 2019; Mayer, 2014b; Mayer & Fiorella, 2014; Mayer & Pilegard, 2014). The Life Sciences pre-service teachers in Group 1 perceived asynchronous teaching as beneficial, because they could watch the pre-recorded lessons at any time. They described how these pre-recorded lessons showed their lecturer reading off PowerPoint slides, thus including both conversational speech and on-screen text. Group 2, however, reported that they struggled to motivate themselves to watch the videos. Group 2 suggested that the videos be shortened to 20 minutes each so that they do not lose attention. This showed that they had an understanding of the importance of presenting information in short, learner-paced segments. Both groups also described a Demo video recorded by their Life Sciences methodology lecturer, which was perceived as effective. Life Sciences pre-service

teachers' experiences of the Demo video are described in more detail under the 'Representations' section.

A teacher's ability to use online digital educational technology to transform their teaching strategies and representations effectively is an indication of good TPACK (Koehler & Mishra, 2009). The Life Sciences pre-service teachers perceived that their Life Sciences methodology lecturers had developed TPACK when they used the asynchronous approach, as they managed to use online digital educational technology to create and record lessons perceived as beneficial. However, this approach was not perceived as adequate for teaching Life Sciences on online platforms at schools, due to a lack of real-time interaction with teachers and peers.

In this case, the Life Sciences pre-service teachers' TPACK was underdeveloped as they had limited knowledge of how to plan and create pre-recorded lessons. They understood the importance of presenting information in short, learner-paced segments, and through the use of conversational speech with on-screen text, but they lacked knowledge of how asynchronous teaching could be made more effective through the use of online digital educational technology such as high-quality pictures, high-quality animations and with cues that highlight important information (Choe et al., 2019; Mayer, 2014b; Mayer & Fiorella, 2014; Mayer & Pilegard, 2014).

Flipped classroom approach

The flipped classroom is a teaching strategy that uses a combination of both synchronous and asynchronous approaches (Marina & Ridlo, 2021). The asynchronous component occurs when learning material is given to learners outside of class time. This is then supplemented with online, synchronous lessons (Marina & Ridlo, 2021). For this approach, teachers are encouraged to give learners various options to learn material, for example, from books, videos, audio files, or any other types of materials that cover a topic. Afterwards, learners are expected to demonstrate understanding of this content through activities and discussions that take place during live class time (Edudemic, 2015; Jeffries & Hugget, 2014; Russell & Hollander, 1975; Sergis et al., 2015)

The Life Sciences pre-service teachers were not familiar with the term 'flipped classroom', but did describe the approach. Group 2 described how one of their Life Sciences and Life Sciences methodology lecturers would give them resources (videos and PowerPoints) to work through and research on their own, before discussing them with peers on an online discussion board. Thereafter, a synchronous lesson scheduled by the lecturer would be used to discuss the learning material as a class. This strategy was found to be very effective, but students did feel that they needed to have a strong willingness to learn, in order to benefit from it. The flipped classroom helps learners to practise self-learning, making them more aware, responsible, and independent (McCarthy, 2016; Rindaningsih, 2018).

For Life Sciences specifically, teachers could use the flipped classroom approach to facilitate virtual laboratory activities, by showing learners events and processes that may be impossible to show through traditional in-person teaching (Malto et al., 2018). However, virtual laboratories do not offer a hands-on approach. Therefore, Group 2 suggested that for teaching Life Sciences on online platforms in schools, the flipped classroom should begin with a synchronous online lesson to teach learners about a new concept, using direct instruction. Thereafter, learners would be required to use resources to complete practical activities on their own, thus giving them a hands-on experience rather than using virtual laboratories. Finally, another synchronous online lesson should be scheduled to share results and experiences.

In a typical flipped classroom, direct instruction is moved to the individual learning space, while online platforms are transformed into a dynamic, interactive learning environment, where the teacher guides learners as they apply concepts and engage creatively in the subject matter (Malto et al., 2018). In the suggested flipped classroom, direct instruction is used on online platforms while the individual learning space is transformed to allow learners the opportunity to apply themselves and to engage with Life Sciences content using a hands-on approach. The benefit of this suggested approach is that the hands-on component would make learning experiential and meaningful, contribute to the development of cognitive skills, and promote interaction (Agustian, 2020; Yesiloglu et al., 2021; Yorkovsky & Levenberg, 2022). However, this could be a missed opportunity to show learners events and processes on virtual laboratories that may be impossible to show through traditional in-person practical work (Malto et al., 2018).

The Life Sciences pre-service teachers perceived their Life Sciences and Life Sciences methodology lecturers as having well developed TPACK when using the flipped classroom approach as they were able to use online digital educational technology to present content in an interactive and engaging manner. The Life Sciences pre-service teachers also displayed well developed TPACK when suggesting the flipped classroom for teaching Life Sciences on online platforms in schools. The TPACK of the Life Sciences pre-service teachers and perceived TPACK of the Life Sciences and Life Sciences methodology lecturers were developed and not yet well established as this flipped classroom strategy was not described with online digital educational technology being used to transform teaching (Koehler & Mishra, 2009).

Hybrid teaching

The flipped classroom can also be used as part of a hybrid approach that includes the online delivery of content, while face-to-face classes are used for completing practical projects and tasks (Malto et al., 2018). Hybrid teaching includes instruction where content is delivered both in-person and on online platforms (Basilaia & Kvavadze, 2020; Mossavar-Rahmani & Larson-Daugherty, 2007).

Many students and learners were not prepared for, nor used to, learning online, causing a number of unwanted effects, including social isolation (Hammond et al., 2020). Focus Group 3 was the last one to meet; this was scheduled at a period when the university was phasing in in-person exams. This group included B.Ed. third-year students who were meeting their peers for the first time since their degrees began in 2020. The context of this focus group made them realise how much they missed face-to-face interaction, and this influenced their opinions of the best teaching strategy for teaching Life Sciences online in schools. They were the only group to suggest the hybrid approach to teaching Life Science in schools. The motivation for using this approach is that it would give learners the opportunity to interact with their teachers and peers not only online, but also in-person, which was perceived as vitally important for learners' overall wellbeing.

The Life Sciences pre-service teachers had underdeveloped TPACK when describing the hybrid approach, as they were only able to describe how hybrid teaching would allow for interaction. However, they did not describe details on how online digital educational technology could be used to transform teaching using the hybrid method, how class activities could be divided between face-to-face and online classes, what role the teacher should play, or how class participation would be facilitated (Mossavar-Rahmani & Larson-Daugherty, 2007). There are many more benefits of hybrid teaching other than in-person interaction that the Life Sciences pre-service teachers did not consider, for example, learners can review work on online platforms at any time and place; they can review work online that is too long to review in person; in-person class time can then be used for discussions and hands-on activities; and hybrid teaching can be used to cater to all learning styles (Mossavar-Rahmani & Larson-Daugherty, 2007). Furthermore, the Life Sciences pre-service teachers did not consider how hybrid teaching could be used to teach Life Sciences specifically, for example, online platforms can be used to review experiment simulations as a pre-learning phase, which can then be followed by in-person laboratory experiments and other practical activities (Sun et al., 2023).

Representations

Multiple representations, rather than single representations used alone, can help learners to construct a deeper understanding of complex Life Sciences concepts or system structures (Ainsworth, 2014; National Research Council, 2012). Group 3 discussed how Life Sciences includes content and terminology that could have different meanings in other scientific disciplines. This could lead to misconceptions among learners. To solve this challenge, Group 3 suggested that multiple representations be used to represent Life Sciences content.

Some representations that Life Sciences teachers can use include visual representations, such as diagrams, natural drawings, graphs, charts, tables, pictures, animations, or objects (Roth et al., 2006; Treagust & Tsui, 2013). Scientists and Life Sciences teachers agree that visualisations are important for learning, practising, and communicating science (Ainsworth & Newton, 2014; Eilam & Gilbert, 2014;

Matthewson, 1999). All focus groups recalled their Life Sciences and Life Sciences methodology lecturers using visualisations such as PowerPoint slides, pictures and reading material. However, these representations were not viewed as something exclusive to online teaching. PowerPoint slides were perceived as ineffective, and it was suggested that they should not be used alone and should rather be accompanied by voice-overs, videos, online simulations and other experimentation software.

Other representations that can be used for online teaching include digital educational technology like simulations, augmented reality and virtual reality, and 3D printers, virtual labs and e-books (Daniel & Woody, 2013; Emine et al., 2018; Treagust & Tsui, 2013). Groups 2 and 3 suggested that for teaching Life Sciences on online platforms in schools, the use of online simulations, applications and games would be the most beneficial. Group 2 recalled one of their Natural Sciences methodology lecturers using an online simulation, PhET, to show how electric circuits work. Group 3 recalled one of their Genetics lecturers using an online application called OWL for online assessments. Group 3 further suggested that schools need to be willing to invest in good quality Life Sciences simulations and applications, rather than expecting teachers to rely on free versions. Another representation mentioned was a Genetics e-book that Group 3 described their Genetics lecturer using. This e-book was interactive with embedded quizzes.

Other representations that are both visual and digital that can be used are pre-recorded lesson videos. When discussing the asynchronous teaching method, Group 1 vaguely described that the pre-recorded lessons they were given, showed their Life Sciences methodology lecturer reading from PowerPoint slides. This is an example of didactic videos used to teach the theoretical component of a subject. This may have included the Pen Tablet, Talking Head, or Slides On/Off styles. The Pen Tablet style is described as the lecturer using an interactive pen tablet, with which they can point and draw directly on the lesson slides. The Talking Head style video is similar to the Pen Tablet, but it enables the teacher to actually be in the video, appearing as a ‘talking head’. The Slides On/Off style is similar to the Talking Head style, except that either the lesson slides or the teacher are displayed separately (Choe et al., 2019).

Other didactic videos include the Classic Classroom, the Weatherman and the Learning Glass. The Classic Classroom involves the teacher using both a PowerPoint

presentation and a chalkboard, which would not have been possible during the COVID-19 pandemic, as the university was closed to both students and lecturers. The Weatherman and Learning Glass features are more expensive and only available to those who can afford them. The Weatherman is described as the teacher standing in front of a large green screen projecting content, but the teacher cannot draw or write in real-time. The Learning Glass utilises an LED-illuminated low iron glass that functions as a whiteboard, which appears in front of the teacher (Choe et al., 2019).

Non-didactic videos are used to supplement instruction with a more practical component. Examples of non-didactic videos include the Demo and Interview styles. The Demo style captures the teacher doing practical tasks such as scientific experiments (Choe et al., 2019). Group 2 suggested that Life Sciences teachers pre-record Demo videos, showing learners how to conduct scientific experiments. They suggested this after recalling how one of their Life Sciences methodology lecturers recorded a Demo video for them, showing how to design and set up a scientific practical assessment with stations. Group 3 even suggested that learners could get involved with making their own Demo videos showing simple scientific experiments at home. Finally, the Interview style, not described in this study, captures the teacher sitting in front of a digital screen, in conversation with an off-screen interviewer. The interviewer asks a question that the teacher addresses while displaying relevant information on a digital screen. The questions are displayed as text in full-screen mode before each response (Choe et al., 2019).

Groups 2 and 3 further suggested the use of YouTube videos for Life Sciences content, especially those on the channels ‘Amoeba Sisters’ and ‘Crash Course’.

The representations above can be presented on various online platforms. Group 2 suggested the use of social media platforms for representing Life Sciences content. Social media has become widely adopted by learners and therefore has the potential to be a valuable tool for communication between teachers and learners. Social media can be defined as websites and technological applications that allow users to share content and to participate in social networking. The use of social media encourages high levels of self-motivation, while also being autonomous and informal. This may help learners in becoming lifelong learners. It is also important to note that learners may become easily distracted by social media platforms such as Facebook, Twitter

and Instagram. Therefore, for the purposes of teaching and learning, professional websites like LinkedIn and ResearchGate may also be considered as social media platforms, even though they may not be colloquially considered as such (Dabbagh & Kitsantas 2012; Leyrer-Jackson & Wilson, 2017). Some Life Sciences pre-service teachers thought that social media would help motivate learners to learn, and others thought that learners use social media to get away from school and learning and would therefore be distracted by it. The group then suggested that a social media platform that is not currently very popular for socialising be chosen to use for teaching and learning. The suggested social media platform was Facebook, as it was currently perceived as an unpopular platform for socialising amongst young people. Groups 1 and 2 suggested other online platforms for presenting representations, namely Discord, One Note, Google Classroom and District 4.

The TPACK of the Life Sciences pre-service teachers and the perceived TPACK of the Life Sciences and Life Sciences methodology lecturers was well established in this regard, as representations such as visualisations together with unique digital educational technology were described that could be used to transform online Life Sciences teaching.

Advantages and disadvantages of online teaching and learning

At the start of the COVID-19 pandemic, many teachers were unprepared for adapting their classroom-based practices to emergency online teaching (Luz, 2020). Teachers had little to no knowledge and skills related to using digital educational technology on online platforms, and had difficulty designing online lesson plans, learning materials and assessments (Ferri et al., 2020). Groups 1 and 3 believed that many teachers may not have had experience using online digital educational technology in the past. This may have caused many challenges, including teachers not being able to assess whether their learners need support and not being able to support them fully.

As schools transitioned to online teaching during the COVID-19 pandemic, they also faced many challenges related to technology, for example, connectivity issues and unequal access to digital educational technology (Arcueno et al., 2021). During the

COVID-19 pandemic in South Africa, educational institutions were forced to close. To preserve the academic calendar, many well-resourced schools in urban areas moved teaching to online platforms. However, schools in rural areas encountered various challenges, for example, inadequate teaching and learning infrastructure, power outages or lack of access to electricity, inadequate numbers and quality of personal laptops, inadequate network service from service providers, and limited computer skills (Ajani, 2023; Burgess & Sievertsen, 2020). All the focus groups described the disadvantages of online education in the context of South Africa. They described that in South Africa, there are well-resourced and under-resourced schools. Well-resourced schools would have had access to digital educational technology for emergency online teaching during the COVID-19 pandemic, while under-resourced schools lacked digital educational technology and internet connectivity. This led to unequal access to digital educational technology amongst schools in the country during the COVID-19 pandemic. This was perceived as a barrier to transforming education in South Africa, as the curriculum cannot be changed to include the integration of digital educational technology until all schools have equal access to it.

Another barrier to online teaching is language distance, which can be described as teachers teaching in learners' second or third languages, using an unfamiliar accent, and the use of dialect, slang, jargon, colloquialisms, acronyms and abbreviations. This causes communication and language barriers between teachers and learners online (Berge, 2013). Group 1 discussed language barriers on online platforms. They described how teachers would not be able to support learners who do not speak English as a home language. However, they also discussed that recorded lessons could help these learners improve their English, by watching them in their own time and pausing where needed. Communication on online platforms could be improved by providing clear statements about the goals of the lesson and activities; providing navigation assistance so students know where online resources are located; clearly linking content and activities to learning objectives; using clear, concise, unambiguous language during lessons and when communicating through other communication channels; using communication channels that students prefer; providing summaries, additional resources, and feedback to help students evaluate their learning and finally, design the online classroom in a way that promotes student interaction (Berge, 2013).

For Life Sciences specifically, laboratory and practical lessons are essential and important. “Learning by Doing” makes learning experiential and meaningful, contributes to the development of cognitive skills, and promotes interaction (Agustian, 2020; Yesiloglu et al., 2021; Yorkovsky & Levenberg, 2022). Group 1 discussed the importance of having a hands-on approach to teaching and learning Life Sciences. They described how learning about the heart would be more beneficial when doing a live dissection rather than looking at it on online representations.

Despite the challenges of online teaching during the COVID-19 pandemic, online platforms provided a convenient means for communication between teachers and their learners (Arcueno et al., 2021). The Life Sciences pre-service teachers in this study discussed how learning online helped them to develop important skills such as time-management and research skills. It gave them the opportunity to work through content at their own pace and catch up on any work they were falling behind in, thanks to recorded lectures. This led to the development of skills such as self-paced learning, self-regulated learning and self-discipline, as also reported by Arcueno et al. (2021) in the Philippines.

5.2. LIMITATIONS

Limitations refer to constraints in a research study that are beyond the control of the researcher. Limitations may include time, financial resources and access to information. Time, financial resources and access to information were not limiting factors in this study (du Plooy-Cilliers et al., 2021). The study focused on Life Sciences pre-service teachers’ experiences of learning Life Sciences online and their perceptions of how Life Sciences should be taught online in schools. The participants were all enrolled in an education qualification, either B.Ed. or PGCE and were available to participate in focus group interviews either online or in person at a time that was convenient to them. The study was not limited to current pre-service teachers but was limited to pre-service teachers who experienced learning Life Sciences or Life Sciences methodology lectures on online platforms at university. There were minimal costs involved in the study, such as transportation costs to get to the university for the in-person and hybrid focus group interviews. Access to collecting information was

granted by the Dean of the Faculty of Education at the university in Gauteng province and the students signed consent forms to confirm their participation in the study.

Limitations can come up when there are shifts in conditions during the course of a study (du Plooy-Cilliers et al., 2021). An important limiting factor in this study was the changing COVID-19 lockdown restrictions and regulations. South Africa made use of various alert levels to help combat the spread of COVID-19 between the years 2020-2022. These alert levels ranged between 1-5. Alert Level 1 allowed for most normal activities to take place, with some precautions and health guidelines that needed to be followed, for example social distancing, mask wearing and sanitising or washing of hands. During Alert Level 2, social distancing was a requirement and restrictions were placed on social gatherings. There were restrictions on the number of people allowed to attend social gatherings. During Alert Level 3, there were greater restrictions on the number of people allowed at social gatherings. These restrictions extended into workspaces. Alert Level 4 enforced extreme precautions and restrictions on social gatherings. Only some activities were allowed to resume. Finally, Alert Level 5 enforced drastic measures to contain the virus. This included curfews and only being allowed to go out for groceries and essential services (South African Government, 2024).

When data was collected in the middle of 2022, an adjusted Level 1 alert was in place. This allowed for most normal activities to occur with some precautions in place. The university was still offering lectures on online platforms and was set to resume face-to-face classes in semester 2 that year. They were in the process of starting to host some examinations in-person on campus (South African Government, 2024).

The context of the focus group interviews were therefore limited by these COVID-19 alert levels. The first focus group took place online as none of the students were attending class in-person. Focus Group 2 took place using a hybrid approach as the students were still learning on online platforms but were starting to go back to campus to use the facilities and resources. Finally, Focus Group 3 took place in person as all the students wrote an in-person examination on campus on the day.

Another limitation that was beyond the control of the researcher was connectivity issues. During the first focus group interview, which took place online on Microsoft Teams, two participants experienced connectivity issues and had to leave before the

interview came to an end. During the second focus group interview, which took place in a hybrid context, one of the participants who joined online on Microsoft Teams experienced connectivity issues and had to leave before the interview ended.

Along with defining the limitations of a study, delimitations may also be described. Delimitations are a result of specific decisions made by the researcher (du Plooy-Cilliers et al., 2021). They may be referred to as the parameters of a study and important to giving a study more direction and focus. Examples of delimiting factors include the purpose of the research, the research questions, the theoretical framework and the population. The delimitations of this study included the purpose, which was to explore Life Sciences pre-service teachers' experiences of learning Life Sciences and Life Sciences methodology modules on online platforms in university. Then, based on these experiences their perceptions of how Life Sciences should be taught on online platforms in schools was explored. The research questions as delimitations specifically asked about the teaching strategies and representations used to teach Life Sciences content on online platforms. It also asked about the Life Sciences pre-service teachers' perceptions of the advantages and disadvantages of teaching Life Sciences content on online platforms. The Theoretical framework used was the TPACK framework. The TPACK theoretical framework helped guide the study towards an understanding of how representations such as visualisations and digital educational technology could be integrated into teaching strategies on online platforms for Life Sciences content. Finally, the population as a delimitation was that it only included Life Sciences pre-service teachers who have experienced learning Life Sciences content on online platforms at university.

5.3. IMPLICATIONS

University lecturers, having experienced the sudden shift to online teaching, might have developed insufficient teaching strategies. The nature of the sudden change did not allow for systematic training to take place, nor did it allow time to develop ideal ways of teaching on online platforms. Instead, lecturers had to adapt to teaching on online platforms in a very short time and struggled to maintain social, cognitive and teaching presence in the process. This may contribute to future research on online synchronous teaching in a higher education context.

This study also highlighted how Life Sciences pre-service teachers preferred online teaching strategies and representations that promoted interaction and engagement in the online environment during the COVID-19 pandemic since 2020. This may impact future studies that explore online education in a post-COVID-19 pandemic context.

This study provided insight into Life Sciences pre-service teachers' experiences and perceptions of the following online teaching strategies: synchronous teaching, asynchronous teaching, the flipped classroom approach and hybrid teaching. It also described their experiences and perceptions of the use of visualisations and online digital educational technology as representations for online teaching. This may contribute to further studies on these methods and representations for online teaching.

Another important finding was that Life Sciences pre-service teachers perceived scientific experiments and practical activities to be very important components of Life Sciences education. This may have an impact on future studies on online education for science-related subjects with practical components.

A final key finding in this study was that all focus groups expressed worry and concern about the digital divide in South Africa during the COVID-19 pandemic. This may impact future research on digital technology integration in education in a South African context.

5.4. CONCLUSIONS

Since the start of the COVID-19 pandemic in 2020, a growing number of educators found themselves teaching in an online classroom. The purpose of this study was to gather data to answer the research question: "How do Life Sciences pre-service teachers describe their perceptions of best practice for teaching Life Sciences on online platforms in schools, based on their experience of learning Life Sciences on online platforms at university?" To answer this question, three sub-questions were asked and answered. The first sub-question was: "What teaching strategies and representations did Life Sciences pre-service teachers perceive to be effective when they were learning Life Sciences on online platforms at university?" The Life Sciences pre-service teachers described how their Life Sciences and Life Sciences

methodology lecturers used synchronous, asynchronous and flipped classroom teaching strategies on online platforms at university. The asynchronous and flipped classroom methods were perceived as more effective than the synchronous teaching strategy, as these lessons were lacking in social, cognitive and teaching presence. They also described multiple effective representations in the form of visualisations and online digital educational technology that their Life Sciences and Life Sciences methodology lecturers used, namely, PowerPoints, pictures, reading material, online simulations and applications, an e-book, YouTube videos and Demo videos.

The second sub-question asked was: “What teaching strategies and representations do Life Sciences pre-service teachers perceive to be effective for teaching Life Sciences on online platforms at schools?”. The Life Sciences pre-service teachers described how synchronous, flipped classroom and hybrid teaching strategies would be best suited to teach Life Sciences on online platforms in schools. They did stress that synchronous methods should take social, cognitive and teaching presence into consideration. They also described multiple representations in the form of visualisations and online digital educational technology that could be effectively integrated into online teaching for Life Sciences in schools, namely PowerPoints, pictures, experimentation software (in the form of online simulations and applications), YouTube videos and Demo videos.

The final sub-question asked was: “What are the advantages and disadvantages of teaching Life Sciences on online platforms, as perceived by Life Sciences pre-service teachers?” The perceived disadvantages of online Life Sciences teaching were unfamiliarity with online platforms and online digital educational technology, the digital divide between under-resourced and well-resourced schools in the country, communication and language barriers and missing out on hands-on experiences. The perceived advantages included the development of time-management and research skills, more flexibility, and access to recorded lessons at any place and time.

The TPACK framework was used in this study, and it was found that the Life Sciences pre-service teachers perceived their Life Sciences and Life Sciences methodology lecturers as portraying well developed TPACK. Although they described their lecturers using some effective teaching strategies (synchronous teaching, asynchronous teaching and the flipped classroom) and some effective representations (visualisations

and online digital educational technology), they described these practices as lacking in interaction and engagement; more specifically social, cognitive and teaching presence.

The Life Sciences pre-service teachers' TPACK was well established as they were able to describe how teaching strategies (synchronous teaching, the flipped classroom and hybrid teaching) and representations (visualisations and online digital educational technology) could be used to promote interaction and engagement when teaching on online platforms. They described how online digital educational technology could be used to replace and replicate a traditional face-to-face class, for example, with tools available on online platforms (chat function, polling function and breakout groups), videos, simulations, and applications. However, they were not able to suggest ways in which online digital educational technology could be used to transform teaching on online platforms in a way that would not be possible in-person.

Through this study, a better understanding of Life Sciences pre-service teachers' experiences and perceptions of TPACK of online teaching now exists. Although further research should be conducted in this area, the current study represents an important step in exploring how Life Sciences education has been changing since the start of the COVID-19 pandemic in 2020.

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Appendices

APPENDIX 1: INTERVIEW TRANSCRIPTS

Focus group 1

Interviewer	As I've said earlier, my research is on student teachers' experiences of learning Life Sciences modules online and how they think Life Sciences should be taught online in schools. Remember that this interview remains confidential, so I will not be revealing your identity in my research report. Only I will have access to this recording and my supervisor. Okay, do you guys have any questions before we continue?
Participant U	None for me.
Interviewer	Thank you. So, my first question is: "Do you think that Life Sciences could be taught effectively in schools using online learning platforms?
Participant L	When you say schools, do you mean high schools?
Interviewer	Yes, high school. So, Life Sciences is generally taught from grade 10-12. However, there is Natural Sciences in primary school in Grade 8 to 9 that sometimes has a Life Sciences component to it. But, for the sake of this study, let's focus on high school.
Participant L	Okay.
Interviewer	Okay. So, do you think that Life Sciences could be taught effectively in schools using online learning platforms?

Participant U	Uhm, I would say given the circumstances. So, for example it's not well, it's well, it won't work if it's like a rural area, because none of, if not most of those students don't have access to computers, internet, Wi-Fi, all of that. But, if you move to like a different uhm, you know area for example, if you're in Sandton then yeah sure. It's the locality of the students.
Interviewer	Yes, and that's very important when it comes to South Africa, our context.
Participant U	Yeah.
Interviewer	Okay anybody else?
Participant M	That's possible, but there's a lot of things you need to happen. First, you need the students to be participating in working for their education. You need the teacher to be exciting and interested. You need all the technology in place. So, it's an entirely different subject.
Interviewer	Yes, definitely. Thank you. I see participant L and participant R also had their mics on.
Participant L	Yeah. I just wanted to add the problem of the language used in Life Sciences. I think that will also be a barrier. Especially in like, if we start teaching online, because I think a lot of students struggle with the language used in Life Sciences. So us moving online like that would create another problem.
Interviewer	Can you elaborate on that? How would language become a problem online specifically?
Participant L	Because most of the time students don't understand this is like English, right? Because they struggle with reading. For me, like with

	meaning and stuff like that, so me not being there in class would also create another barrier because I know you can use maybe like vernacular online and stuff like that but still, you not being physically there to explain some of the concepts and like examples and stuff like that, could create another barrier especially for students that still struggle with just understanding English.
Interviewer	Yes, no definitely. That's very interesting insight. Thank you.
Participant M	If I may.
Interviewer	Yes.
Participant M	I think teaching online might actually help with the language barrier. I remember during lockdown in universities, teaching online, there was a study that said when people are able to go back and watch the recording of the lecture, do it at their own speed and pause things and take a bit of control, it improved understanding in the second language.
Interviewer	Yes, Okay.
Participant M	So, in that regard maybe with the terminology, teaching online may help if you use it right.
Participant L	I don't think they would have data to access like recordings and stuff like that. So, like participant U said, if we in public schools, we already lack textbooks and stuff like that. Do you think they would have data to firstly listen to the online lecture and then secondly, go back and watch the recording?
Participant M	That's true. I mean, you might not be able to utilise the resource that you have.

Participant L	Exactly, so in that scenario, that would be like just an ideal situation where we in maybe Sandton or in Pretoria where students have access to Wi-Fi or data plans and stuff like that. But, then if we move to like a township where students already struggles just finding a school that has textbooks or desks or chairs and stuff like that, then we move online where we just create a plethora of problems.
Interviewer	Yeah, it all depends on what perspective you look at this.
Participant L	Yeah.
Interviewer	And it also depends on the context. Thank you. That's very interesting.
Participant R	Okay, well for me, I think it can be both. But then even with the students in Sandton for example, those that can utilise the resources that are available to them, let's say for instance, you're doing practicals, for me, I feel like when you're doing practicals, it's effective. If these learners can see and touch, like let's just say for an instance, you disable, dissect, dissecting a heart and I mean a sheep's heart, for example. So, I feel like those student needs to touch that heart for them to have a feel and to be in touch with the content and to understand more of it. So, I feel like with practicals, it can be at a disadvantage in a way.
Interviewer	No, that's interesting and I'm glad you're thinking along the lines of Life Sciences. Specifically, because like you said, it's a very practical subject.
Participant R	Yeah.
Interviewer	Yes, Okay. Thank you very much. So, my next question was actually going to lead to: “Briefly explain why you think this is?”. But I think

	you've all covered that. Before I move on, does anyone else want to add on to that question: “Do you think Life Sciences could be taught effectively in schools using online learning platforms?”? Okay, I'm going to move on.
Participant L	Oh sorry?
Interviewer	Really no problem. Go for it.
Participant L	And I also wanted to add the fact that I think it would only work with like newer generations of teachers that are well versed with technology and stuff like that, because like the older generation, especially in high schools, they like maybe like 40, 50 years old and they've like never used most of the equipment and stuff like that. So, I think that will also be doing a disservice to the students or the learners if they're not well versed with the methods of teaching well, that would be online.
Interviewer	Definitely. Yeah, thank you for that. Okay, so, the next part of my interview is all about teaching strategies. Okay, so, my first question over there is: “What teaching strategies did your lecturers use when teaching you Life Sciences modules on online learning platforms?”. Anybody? What teaching strategies did your lecturers use when teaching you Life Sciences online?
Participant M	Well, I remember for me I was doing Ecology, so it was a very interesting subject. The lecturer would explain and almost tell a story about what's going on and it's very easy to pay attention. Then you'd go off and you would be given quite complex readings on the subject and do a lot of it ourselves.

Interviewer	Okay
Participant M	But I'm not sure how that really applies into high school Life Sciences.
Interviewer	Okay, so when I say Life Sciences modules online, it could refer to didactic modules as well, where you learn to teach Life Sciences online or teach Life Sciences, for example VLW. Okay, so what teaching strategies did your lecturers use when teaching you Life Sciences related modules online?
Participant R	I don't know if this is our place, but then when I was doing my undergrad the lecturer is mainly, they just, we just used to do online quizzes like for…, they just use online for assessments like, yeah.
Interviewer	Yeah, no, thanks. Please elaborate on that.
Participant R	No, you do content face to face, then when you're done, you do assessments online on your own.
Interviewer	Okay.
Participant R	Yeah.
Interviewer	Okay. Anybody else? What teaching strategies did your lecturers use when teaching Life Sciences related modules online?
Participant L	I think in terms of VLW it was mainly just like a lot of talk and chalk where she would just present the content and then we would have to listen. Yes, just listen and then at the end, we'd maybe just ask a few questions, if maybe we don't understand something and then we just end the session there. So, it wasn't a lot of inquiry-based teaching or inquiry-based learning. It's mainly the lecturer is talking for most of the

	lesson and then we just put in like a two cents, right like here and there. Then it would just be the end of the session just like that.
Interviewer	Okay, perfect. Anybody else want to add on to that? Okay, based on that question, do you think that these teaching strategies were effective? Or, in other words, did they help you to learn?
Participant L	Personally, I don't think it was effective. Okay, based on my answer of the previous question because I don't think it prepares you for the practical or like the teaching practicals cause you just get there and you just know the theory behind like teaching Life Sciences, but most of it was like before the first practical. It wasn't as practical. So now I think the lecturer's including more examples of how to approach things in the classroom and stuff like that. So now I feel like it's becoming much more helpful, but it wasn't at first.
Interviewer	Okay. Can you elaborate on what exactly wasn't helpful and what is helpful?
Participant L	Uhm, well at first it was just a lot of theory. Like it wasn't practical like, I don't know how to put it, but it was just, I don't know. Like, it wasn't how you'd like, maybe handle a certain situation in class. You know, like a problem in class about maybe teaching Life Sciences. Like, maybe back to the language problem, we don't do a lot of problem-based learning. I don't know how to word it, but it was just a lot of theory on maybe how to maybe do something in like an ideal situation. But now when you get to class, you don't find any of that.
Interviewer	Yes.
Participant L	So, we're just left there to, you know, work on your feet.

Interviewer	Okay, and what would you say was helpful?
Participant L	Now, Okay, maybe like the past two, three lessons, we are using much like more examples how to maybe teach a certain thing. Now like she's introducing us to like maybe teaching strategies and teaching methods how to handle a situation. Certain situation of like maybe learners not wanting to participate and stuff like that. So now that she's including more examples it becomes more practical than it was earlier.
Interviewer	Okay, perfect. Uhm, anybody else want to add on to that? Were these teaching strategies effective? Yes, participant R?
Participant R	Yeah, with VLW, right, because at the beginning, she was like, she records the lectures. Then we can watch them in our own time. I think the good thing about it is you don't have to miss class. Like if it was contact classes there were going to be possibilities for you to miss class, but then if it's recorded, then you watch it at your own time. That is, yeah, that is good in the sense that it's you don't have to miss the class. You can just watch the lesson anytime that you wanted to. It's there anytime you want to. Uh, I think, yes that's how it helped. That's how online learning helps yes and with the example that I gave earlier of doing assessments online for my undergrad, I think it was helpful in the sense that it prepared you for exams. Like for me during those online quizzes after every delivery lecture, actually prepared me to do better in exams. I think yeah, that was the only thing that made it helpful.
Interviewer	Perfect, Okay. Anybody else? Yes, participant R. Go on. Okay, anybody else want to add on to that? Uh, participant M, I saw you had your mic on. Did you want to say something?

Participant M	Just that the most effective parts were the practicals we did. And, then coming back to the practicals, I think we understood a lot of what the lecturer was saying better, but she was able to tell us more stories that we would relate to. So, part of her teaching strategy changing, also we changing a little bit as well, but I most agree with everything participant L said.
Interviewer	Okay, perfect. Thank you. So, what teaching strategies do you think could have worked better in these Life Sciences modules that you were taught online?
Participant M	I would say the biggest thing is the modules lose attent… well, you lose attention quite quickly in a long module and not so much in VLW, but some of the bigger ones, LNT specially. So, a lot of, I'll call it time wasting. Uhm, which is kind of fine for us, but I imagine will be a lot worse for a student who is struggling with data, so I would say break the concepts into smaller 20-minute videos and post them independently.
Interviewer	Okay, that's interesting. Uhm anybody else? What teaching strategies do you think could have worked better? Anybody? Participant L, I remember you said that these teaching strategies were not really effective. What do you think could have been done to make it more effective?
Participant L	Like I said, it's just like, using real life examples would have been much more better, like to prepare us especially for the first practical. Uhm, and for teaching Life Sciences and stuff like that, I get like, because the first quarter, yeah, we don't have a lot of assessment type, yeah, types of activities where you'd like learn how to set a certain assessment or do 12345. And I get that we need to learn that as well, but then that's not all you do as a teacher when you get to

	high school. Don't just get there and set question papers. You have to actually teach the students something. So, I know that like we have other modules that like prepare us for that, but I think for Life Sciences, I don't know how, she could have just included much more practical ways of tackling maybe the curriculum and stuff like that. Maybe just break down how we could know, you know, do something in class or handle like maybe assigning classworks or creating homeworks and stuff like that.
Interviewer	Okay. Perfect. Anybody else? What do you think? What teaching strategies do you think your lecturers for Life Sciences could have done better? Okay, let's move on. Uhm, so those were questions based on your experiences of learning Life Sciences online at university, specifically focused on teaching strategies. Now what teaching strategies do you think should be used to teach Life Sciences on online learning platforms at schools specifically? So, imagine you're going out there to teach Life Sciences online. What teaching strategies do you think should be used? Anybody? You can think about it for a bit. How would you teach Life Sciences online? Yes, participant R?
Participant R	I don't know. I feel like when I was doing my practicals right, this thing of introducing videos actually, I think it actually helps a lot with students because they become enthusiastic and it becomes stimulating for them to actually watch videos rather than listening to you every day. Yeah.
Interviewer	Okay. That's great. Uhm anybody else?

Participant M	Yeah, probably I would get them on One Note or something and then make a whole bunch of videos about the different points I want to cover, put them in there. Put some videos in and set them so by the end of the week I want you to have done all of this. And then do little quizzes to make sure they do have the points so they can do some work, check themselves. Then end of the week, check everything they've done and give them more freedom to play with it and hope they do.
Interviewer	Perfect. So, are you saying that you would let them do the stuff before a live lesson?
Participant M	Yes, like I said before, I like the idea of short little videos. They don't fill an entire lesson. So, I was aiming for that.
Interviewer	Okay, and then how would that fit into your actual live lesson?
Participant M	I'll probably take one live lesson a week for questions and then the rest of the time, leave it open for them to do the work.
Interviewer	Okay, perfect. Uhm participant L, you had your mic on?
Participant L	Yeah, I think participant M and participant R are trying to like describe inquiry-based learning that is just more focused on the students than it is the teacher you know, because I think we need to move away from that, and through the use of online learning route, help learners to basically teach themselves. It gives them the platform to find the knowledge themselves. So, teachers would just be now facilitators of the knowledge, I think. We need to move towards that and that's what I would aim for.
Interviewer	Okay, perfect.

	Uhm anybody else? Participant N, participant U, participant R you've been very quiet. What teaching strategies do you think can be used to teach Life Sciences online at schools? Okay. So those were some interesting answers but think along the lines of Life Sciences specifically. Uhm is there any specific teaching strategies that could be used to teach Life Sciences specifically online?
Participant M	I'm not sure how easy it is to do, but I remember during lockdown and so my subjects, they had lab, well, they found lab simulators where you could sort of do the experiment on your laptop. I wonder if that's not something that could be used.
Interviewer	No, definitely.
Participant L	Yes, because we also did use simulations in our undergrad like final year, because we couldn't do most of the practicals. So, we do like simulation.
Interviewer	Okay, no, perfect. Thanks guys. Anybody else want to add on to that? So why do you think these teaching strategies should be used when teaching Life Sciences on online learning platforms in schools? These teaching strategies that you just mentioned, why do you think they should be used?
Participant M	Well, inquiry-based learning makes sense for the subject. It's the world around you, you should be interested in it. And you, as a teacher, you should build the interest and let your learners explore that. It's so easy to build interest. You should use it as a resource.
Interviewer	Definitely, Okay.

	Uhh participant R and participant L, since you gave me answers for the previous question, why do you think those teaching strategies should be used?
Participant L	It helps learners be part of the learning process instead of just sitting there just absorbing the knowledge like we used to do in high school. And that just dims, I don't know the interest, cause you just taking in whatever the teachers telling you. So now that would give them the platform to actually go out there and like find out certain things for themselves. I think it would build the interest. Like participant M said, it would help them like develop like some sort of scientific like, I don't know literacy or knowledge on their own. Instead of just sitting there and just waiting for the teacher to just tell them what to think or what to write down and stuff like that.
Interviewer	Okay, perfect. Participant R, would you like to add on?
Participant R	Yeah, I think it's the same reason like just to let the learners have interest in the subject and umh, the other thing is that these learners uhh modern learners, they are constantly on their phones and on the web on the Internet. So, for with the example that I gave with videos, introducing videos as like they now know that they're always on YouTube. So, if you play YouTube videos they can at their own time, go back and look at other videos related to the ones that you showed during class.
Interviewer	No perfect. Uhm, participant U, you had your mic off for a second. Would you like to add on?
Participant U	Yeah, I think I am just adding on to participant R and them. It makes a lesson a lot more interactive and it involves the learners, because I noticed when I went now on teaching practice, my mentor teacher, like, wouldn't, you know, do an experiment or show them a simulation

	or something like that. And then when I spoke to some of them, they were like, no, they want to be actively involved in doing an experiment or watching a simulation of how the experiment would have happened in real life situations. And I think that involves them. In the end, they want to then learn. They don't want to just, you know, I tell you what to do, for example, and then give you, like, give you a scenario and then I, yeah. So, they want to be actively involved in real life situations and then they know how to do real life situations.
Interviewer	Yes. No, definitely. And I think that ties into Life Sciences being such a practical subject. Uhm, thank you. So those were questions on teaching strategies online. Now we're going to look at representations online. Now, Representations is actually a Life Sciences term and it refers to things like visual aids, experiments or even demonstrations. Okay, so it's all of those things that you would use to aid your teaching strategies. Okay. So, my first question there is what representations did your lecturers use when teaching you Life Sciences modules on online learning platforms? Another word for representations would be tools, I suppose.
Participant L	Uhm can you please explain the thing again?
Interviewer	Yeah, sure. So, representations examples would be visual aids, experiments, demonstrations, any teaching aid that they have used to teach the subject, but online. So, what representations did your lecturers use when teaching you Life Sciences modules online?
Participant U	Uhm so I was, uhm, I don't know undergrad quite a while ago when we were still physically on campus, but then I tutored. And what we would do was use simulations in Biochemistry and stuff like that so, uhm, you know those lab practicals instead of having a pactical? Obviously, in a practical situation we would have it online using the simulation.

Interviewer	Yes, no, and simulations definitely classifies as a representation as well. Okay. Anybody else? What representations did your lecturers use when teaching Life Sciences online? Think about VLW perhaps.
Participant L	And I, so I think with VLW, like I said with the first quarter, we did a lot of assessments like setting assessments and stuff like that and then, uhm, there was a part where the lecturer used the CAPS document that would have like certain examples of how to set certain questions and stuff like this. I don't know if that would count as a representation.
Interviewer	Yeah, definitely. It's an aid or tool that you're using to facilitate the teaching.
Participant L	Yes, but that was, that's the one that like sticks out. So, there's, like, certain examples in the CAPS document of how a certain question is like maybe a level 1 question level 2 like yeah, the difficulties and stuff like that.
Interviewer	Okay, perfect. Anybody else want to add on to that, the representations that your lecturers used online for Life Sciences? Participant N, you've been very quiet. Do you want to add on anything?
Participant N	Oh no, I've been very quiet cause ma'am, I've been introduced to this online learning like this year only so it's new. Everything is new but it's very productive for me because I can go back and look at the recording and understand what the lecturer has been saying. So, it's very productive for me yes.
Interviewer	Okay, no, I'm glad. And I'm sure you'll also learn a lot from this session as well.

Participant N	Yes, I'm learning a lot.
Interviewer	I'm glad, Okay.
Participant N	Thank you.
Interviewer	So, these representations that you guys have mentioned, would you say that they are effective or in other words that they help you to learn?
Participant L	Uhm yes, because during my practical, yeah, the first practical, the practical, there was a day where my mentor teacher asked me to set like a spot test for the Grade 11s. So, using like that CAPS document, like you can go back and use the same CAPS document and see like the different levels of questions that you can set for a test and stuff like that. So, it wouldn't otherwise, I'll just be asking you for definitions. Maybe or like, true or false and stuff like that. But because of those learning aids, whatever, now you can you know go back and revisit and set better questions, I guess.
Interviewer	Okay, perfect. Anyone else?
Participant M	I'll say, they're pretty effective, but it's not exclusive to online learning. The same things would've been used in a slide show in person. But yeah, effective.
Interviewer	Okay, so effective but not exclusive to online. Uhm, participant U?
Participant U	Sorry, can you repeat the question?

Interviewer	So, these representations that you guys have just told me about, that your lecturers used online, would you say that they are effective or in other words that they helped you to learn?
Participant U	Uhm not entirely. So yes, in a way, where obviously we get a feel of it, but also we don't get a full feel of, obviously of the practical situation, do you get what I mean?
Interviewer	Yes. No, I get you, because Life Sciences is a practical subject.
Participant U	Yeah, we're not physically doing something and looking at it, but uhm, we kind of get a feel of how it would be.
Interviewer	Okay, no perfect. Uhm. What representations do you think could have worked better? Remember, representations are things like visual aids, experiments or even demonstrations. So, what do you think your lecturers could have done better in terms of the use of representations?
Participant L	I think it will be the lecturer including more demonstrations, because with online learning and her having to record most of the lessons, all she did was just maybe just read over the slides and stuff like that. And I think if there were more demonstrations of, I don't know, certain topics of what she covered, there would be more understanding than us having to just go back and just go online and see what we can. You know, just to aid or like what is it called to like, bridge the gap of knowledge basically from what she said in class and the recording and me having to go online and stuff like that to find more examples or more knowledge or more explanations online on Google.
Interviewer	Okay, got it. Uhm anyone? Yes?

Participant M	Maybe something she should have done is given us hypothetical situations. With a small class it's quite easy to discuss. So, we could have been told if we were given this thing to teach or this subject, or this problem to deal with, how would we deal with that and then discussed as a class and break down what we're doing wrong, what we're doing right and learn from that. So, a lot of information we're given I feel could be learned just as effectively by reading it. We don't need to use our class time for that.
Interviewer	Yes, no definitely. Anybody else?
Participant U	Uhm. Sorry, so I do the Natural Sciences as well and that lecturer would just come in and give you a scenario. So, I get what participant M and them are saying, but I feel like there needs to be a balance. Like give us background and then give us a scenario, don't just go straight into a scenario and then we dropped in the middle of it and we don't know how to kind of handle it. Yes, in the practical world we will you know, the scenarios are different, but at least now if we have some sort of background to be like, Okay, this is the situation. This is how you would handle it and then you get a real-life situation that is similar but not the same. At least you know you have some sort of background on how to handle it. You know what I mean?
Interviewer	Okay. Yes, no, definitely. I'm talking about representations specifically like tools or aids. Is there anything that you think your lecturer could have used to make their teaching better online? Any representations specifically? Remember representations, for example, any visual aids, experiments or demonstrations, but specifically for online. Okay, cool. No problem. The next question. So basically, we've been talking about your experience online at university. Now we're going to

	talk about schools. So, what representations do you think should be used when teaching Life Sciences on online learning platforms in schools?
Participant L	I think like we all mentioned simulations for the practical side of like Life Sciences. And I think that would be like the number one answer, but I think we could also like ask the learners to do the practicals themselves like because most of the experiments or like practicals we did in Life Sciences are things you can do at home. Okay, most of them, not all of them you can do at home. So that learners can also do it themselves instead of just doing it in a simulation. It's still not real life. Yes. So, I think also do that.
Interviewer	Okay, and then how would you incorporate that into online learning?
Participant L	So, it would basically, Okay, basically, maybe just like participant U said which there would be like a background. So, you do the background during class online and then you just let the children do it themselves practically themselves. They maybe, they would come back with the results or whatever they found then we could discuss it over class online again. So, it would be both the teacher and the learners doing something towards the same goal. Instead of just the teacher doing something.
Interviewer	Uhm, no, perfect, because then they're getting a hands-on experience.
Participant L	Yes.
Interviewer	Okay, anybody else? Yeah, perfect. Thanks, participant L. Uhm anybody else?
Participant M	I haven't quite thought it through, but small research projects. Like creating their own resources in a way that they understand. And

	maybe you facilitate them finding the resources you want them to find, or however it may be. I know mind maps were something my mentor teacher liked to use.
Interviewer	Okay great. Uhm anybody else? What representations do you think should be used when teaching Life Sciences online in schools specifically? Participant N, participant U? Okay, uhm, why do you think these representations should be used when teaching Life Sciences on online learning platforms in schools? Participant L and participant M, since you answered the previous question, why do you think so?
Participant M	Well, I like the idea of students making their own study resource. I've just thought of another example one of my mentor teachers did. She would print out a bunch of cards with different terms and definitions, and then they'd have to sit and match them and put them together to learn, well, quite complex definitions. And then they have a resource to use later to study. I think that's valuable.
Interviewer	Okay, but for online specifically?
Participant M	Well, if I…
Participant L	I think so…
Interviewer	Sorry any one can go first. Maybe participant M, you want to finish what you said first?
Participant M	Well, just taught to bridge the gap between not paying attention, not really following what's going on, having a bit of time to do their own work. And also, being online, it's easier to create time and they have

	the Internet as an open resource. It makes sense to me just to use it a little bit.
Interviewer	Yes, definitely. Thanks participant M. Participant L?
Participant L	Like we said, Life Sciences is a more practical subject, so it can't just be based on the theory and just leave it there. So, I think it would be like I said, it would be a disservice not to include such major components of the subject itself. So, if we don't teach learners how to become, practice to become scientists, then we just throw them into the university space where they will actually be performing these experiments and stuff like that, there'll be a gap. Like participant M said, there's just a gap between matric and first year in Varsity. So, in matric all you did was just read about the experiments and the teacher would just sit there and tell you these are the expected results and stuff like that. But you get to varsity where you know nothing about maybe lab etiquette and pipettes and stuff like that. You don't even know what apparatus means. And then now you must get there and just do the practical, which counts for maybe 30%.
Interviewer	Yeah, no definitely, thanks participant L. Does anyone want to add on anything more to that, to representations? Okay, so we're on the last phase of our interview. We're almost done. We've spOkayen about teaching strategies and representations. Now we're going to talk about any other digital educational technology that maybe we haven't mentioned, that maybe you've been thinking about. Okay, so, other digital educational technology could be other tools on online learning platforms. For example, the chat function, the video camera or any other presentation tools that's online. Okay, so my first question there is: "How should other digital educational technology, such as the tools on online learning platforms,

	be used and integrated into Life Sciences lessons on online learning platforms in schools?". How should other digital educational technology be used and integrated into online Life Sciences lessons in schools.
Participant U	Okay, so from my side I'm not sure if I'm understanding the question, but maybe if ma'am gives an example then I can understand better.
Interviewer	Okay, so other digital educational technology are basically tools on online learning platforms. For example, things like the chat function or the video camera or even any other presentation tools that are available online that you may know about. Then, how can any of this be used and integrated in schools specifically?
Participant M	I'm not sure this is quite what you're loOkaying for, but as a self-learning function, maybe towards matric, they could be introduced to Google Scholar and how to do your own research. Because at varsity level, I know that's a skill a lot of people struggle with.
Interviewer	Hmm, no that's perfect. Google Scholar could definitely be considered a tool online. Okay, but what about the tools specifically on the online learning platforms for example, I think you guys use Blackboard Collaborate. As a teacher, what tools do you think you could use on Blackboard Collaborate to teach in schools?
Participant M	Well, on Blackboard…
Interviewer	Or any other online platform.
Participant M	On Blackboard, I know they've got a poll function to take a quick vote from the class. I don't think that's used enough. If we are in person, we

	would be asking questions to the class, trying to get feedback to keep them engaged. And you can do that on Blackboard, with a bit of preparation, but people don't.
Interviewer	Yes, Okay, that's perfect. Participant L?
Participant L	Even the chat box, cause it's most of the time the lecturer just wants to get through the lesson, just finish the content and doesn't want to like go through the chat box where students are voicing, maybe they have opinions or asking questions so that just yeah. If the lecturer keeps on saying no, I'll just loOkay at it later, loOkay at it later, students then don't want to engage anymore. Cause I mean, if I'm voicing my opinion, the lecturer keeps telling me no, I'll read that later, or please ask questions later, then you just get bored or you don't wanna engage anymore.
Interviewer	Yes, there's no engagement. Okay, yes, Okay.
Participant M	Yeah, I agree with that. It's very irritating you not being heard.
Interviewer	Yes, Okay. Participant U?
Participant U	Another thing is we have breakout groups, so I think we can use that and have many discussions. I know usually like some students or learners don't really wanna uhm, you know, ask the teacher like, “I don't understand something”. Also, I apologise for the bird.
Interviewer	It's Okay.
Participant U	Uhm, some… Sometimes they understand their fellow students, like their fellow friends, a lot easier than they would have understood.

	the teacher. So, I think that also would help a lot, like the breakout groups.
Interviewer	Okay, perfect. The next question I think you guys have sort of covered it, but why do you think this digital educational technology should be used and integrated in this way when teaching Life Sciences online in schools? Do you guys want to add on anything more to that? Why you think we should use this other digital educational technology?
Participant L	Uhm, it helps learners to basically construct the knowledge themselves. Yeah, not like the… you see how we just moving into a constructivist type of learning now in the 21st century, yes. So, it would help the, like participant U said, with the breakout group. So, if it's just maybe us as a group, should be other… I don't know if it's PPF or LNT that uses these groups, but you go there, you discuss this certain question amongst yourselves and then maybe you come back now, then you present the knowledge that you shared. So, it would be great for us to do that with Life Sciences. So, maybe just give them a certain, maybe task and stuff so they can break. They can just build the knowledge themselves instead of view the teacher, just like telling them and stuff like that. So, it just helps with that.
Interviewer	Perfect. And anybody else want to add on to that? Okay. We're down to our last two questions, we're almost there. So, my next question is: "How important do you think is the role of digital educational technology in online learning in Life Sciences, in schools? All of this digital educational technology that we've been talking about so far, even the representations, how important do you think it is in online learning for Life Sciences in schools? Yes, participant M?
Participant M	Well, I think it's the difference between a mediocre teacher and actually getting the job done.

	You can't just stand up there and teach.
Interviewer	Yes, uh, elaborate on that.
Participant M	Well, I think online learning is still fairly new, so people haven't really got as comfortable with the different strategies. Like teaching in person is quite intuitive. You know when your learners are drifting off, you have some idea to bring them back and I'll just use the classroom and talk, change the mood and the feel and control what's going on. And you can do that in online learning, just we don't really know how yet. So, you have to be really comfortable with online learning and all the different components of that and they can teach just as naturally as you would in person.
Interviewer	Okay, thanks participant M. Anybody else want to add on to the importance of digital educational technology in online learning for Life Sciences? Yes, participant L?
Participant L	Sorry, that was a mistake, but…
Interviewer	Okay yeah? No problem.
Participant L	Yes, I think it just helps learners just navigate the 21st century that we in right now. So, it is important and yeah, I think that's what I have to say. I don't wanna answer. It was just a mistake.
Interviewer	Perfect, no problem, but that's great. Thank you. Anybody else went to add on to that? Okay, thank you. So, the last question is if there is anything else regarding teaching Life Sciences on online learning platforms in schools that you would like to mention? Anything else that has maybe been playing on your mind that you haven't gotten an opportunity to speak about?

	Just some final words. Yes, participant L?
Participant L	Yeah, I think most of the online learning and it's just sad for ideal situations where learners have, you know all these resources and stuff like that. And I don't think it caters for students that are in, you know, the townships and stuff like this. I think it's still a pretty big divider in the society, so I think I don't know how we would, we could, like try and make sure that these learners are also involved or like included. But I still think it's quite like an alienation tool, type of.
Interviewer	Alienated. Yeah.
Participant L	Yes, alienating tool
Interviewer	No, that's a good way to describe it. Definitely. I think in South Africa, you know our context is very different to other countries. So that's a very important point that you make. Uhm anybody else? Any last few words you would like to say about online Life Sciences education? Anything else at all? Okay. Thank you very much everybody. I'm just going to stop the recording.

Focus group 2

Interviewer	I really appreciate your interest in my research. Before I begin, I just want to ensure you that this interview remains anonymous. Only I will know your identity, and my lecturer will have access to this recording. Once I transcribe this interview for my report, I will be using pseudonyms. So, I won't be using your actual names. So, in that sense, it is going to be anonymous. So, I am going to ask you guys questions. You can decide if you want to do it in an orderly fashion, perhaps. You may raise your hand if you want to answer my question. Or, you could even have a discussion. We will play it by ear. So, let's begin. Let me start by telling you a bit about my research. My research is all about your experiences of learning Life Sciences online and how you think Life Sciences should be taught online in schools. I mean, when you guys get a job one day you never know, you may end up teaching in an online school. With COVID, it is so unpredictable. Schools can go online any time. So, let's begin. Question number 1: "Do you think that Life Sciences could be taught effectively in schools using online learning platforms?". What do you guys think? Do you think that Life Sciences could be taught online in schools? Okay, Participant J?
Participant J	So, I think like all subjects, Life Sciences can be taught in some way online, because COVID has taught us that we can finish a lot of our curriculum online. It is not as effective as it is in person, because it's missing an element.

	It can be taught online. You can use Blackboard and you can use a virtual form for everything. Yeah, and you can still have an element with students, like asking questions, but it is not as good as being in person, but it is still possible.
Interviewer	Yes, no, I agree. Participant T?
Participant T	Yeah, I think it can be taught online, because now like the pandemic is very, very bad, and then we had to learn online, had to adjust. So, it is easier to teach people online because you can make those home demonstrations, simulations and a lot of stuff you can do just to demonstrate what's happening in that Life Sciences topic, especially on investigations. It's easier because we usually watch YouTube videos just to learn more. So why can't we learn online to learn more? So yeah.
Interviewer	You make a very good point. Thank you, participant T. Participant R, you also have your hand up.
Participant R	Yeah, I think it can be taught online, because we can be able to use narrative PowerPoints, maybe YouTube videos, simulations, photographs. But then if we're teaching it contact, we can't be able to use maybe videos or narrative PowerPoints because some schools lack those equipment.
Interviewer	Yes, that's true. You also bring up a very valid point. Not all schools can actually integrate technology into traditional classes. Thank you, participant R. So, yeah, my next question was going to be, "Briefly explain why you think this is?", but I think all of you covered that bit. So, we're going to move on to some questions about teaching strategies.

	Okay, so I am first going to ask you guys: “What teaching strategies do your lecturers use when teaching Life Sciences online?”. Participant R, you have your hand up. Do want to go first?
Participant R	Sorry, I forgot to drop it down.
Interviewer	Okay, do you need some time to think?
Participant R	Yeah.
Interviewer	Okay, participant J, you may go first.
Participant J	So, most of the time they used the online teaching platform like Blackboard, but the method they used was mostly the teach and tell. They told us the content and how it could be asked and then they let us ask questions if we had any, but there was no use of questioning tactics. There was really just teach and tell and not trying to configure for the most part, especially … (unclear).
Interviewer	Okay, so more talk and chalk, as they call it. Okay, participant T or participant R? What do you guys think? What teaching strategies did your lecturers use when they taught Life Sciences? Yes, participant R?
Participant R	Uhm. Lecturers should allow us to engage during online lessons, not just tell us what they expect from us. They should allow us to engage in class, ask questions, things like that.
Interviewer	Yes, and you're saying that they did not allow you guys to engage?
Participant R	Uhm. They did, but then recently she just switched it to just recording lessons, which is not nice.

Interviewer	So, you're saying it became more asynchronous, so you just watch the recording basically.
Participant R	Yeah.
Interviewer	Okay. Thank you, participant R, and participant T, what teaching strategies did your lecturers use for Life Sciences?
Participant T	Ah, the teaching strategy that they used. I think he used participative teaching strategies because like he was giving us like a question that Okay, we participate on, and we find information on and then we just discuss it on discussion board and then during the lesson we just getting it and you understand what I'm saying? We just know what we have to answer. We know what the content of the topic is about. So, we already have more information about the topic that we're going to be discussing in class, so, that's how he did it, yeah.
Interviewer	Okay. So, you're saying that basically you have the content beforehand and so that you're allowed to discuss it when you actually going to class?
Participant T	Yes. Before class. Yeah, we already prepared. What are we going to do in class? Which topic are we doing in class? Not like, Okay, surprise. You're doing this? So, no. So, then we already know what we're going to be doing. We are prepared. We have the lecture slides. We have recordings, we have everything and then in class we just communicate. We just discuss and then give each other like our point of views and everything.
Interviewer	That’s very interesting, thank you. So, tell me one by one:

	"Would you say these teaching strategies were effective?". In other words, do you think that these teaching strategies helped you to learn? Participant J?
Participant J	Yeah, I'd argue actually, yes, because even though it's not very engaging. I remember a lot of times in high school watching YouTube videos. So, it was still possible for me to learn. I wasn't able to get like a master understanding, but I had a basic understanding of the content and how it could be asked. I would say it did help.
Interviewer	Okay. So, in that sense, mainly with the content?
Participant J	Yeah.
Interviewer	Okay, perfect. Participant R, participant T?
Participant T	I feel like it was effective for me because I know, I don't think a strategy is effective to a learner if the learner doesn't want to learn. As for me, I was willing to learn. So, it was very effective to me. It was helpful because I got to search for more information before class. So even things that the teacher didn't know, the lecturer didn't know, I will know them, and I'll share with other people in my class and basically, I'll be helping my peers and then I'll be helping myself too, because I'll be knowing more than I was supposed to know which is very helpful for a person.
Interviewer	Yes. So, because you're actually conducting your own learning by learning the content beforehand and then of course in class, you can decide what to…

Participant T	So, in other ways I'm saying that you are responsible for how you're going to learn, how you want to take on the lesson. It's not the teacher's fault that you don't understand something because we have the mindset of, okay, I don't like how he's teaching, and if you don't like it, you're not going to get it. So, I think it's up to you if you want to understand the strategy. If it's effective to you, you get it, yeah.
Interviewer	I agree. I agree. Thank you, participant T, and participant R? Do you think your teachers' teaching strategies were effective and did they help you learn?
Participant R	So, me at the beginning when we had interactive classes, it was very effective because I could engage with the lecturer, but then right now, because she uses more asynchronous classes, I tend to be lazy to watch the recording so.
Interviewer	Yes. So, you prefer the live interactive one.
Participant R	Yes.
Interviewer	Yes. Okay. Thank you. What teaching strat…, but I think you guys kind of covered this, "What teaching strategies do you think could have worked better?". So, if you had to analyse what teaching strategies your lecturers did use, what do you think they could have done better? Who would like to go first?
Participant T	Okay, alright. Point of view, they are good in everything, but one thing that they should be doing to make learning better, I think they should just give questions to learners. Like we type things out, not like quizzes. Quizzes are so simple, and I don't think a lot of

	learning can take place through quizzes. So, I think after class they can just make a tutorial where we have to write answers down because what you write you never forget. Get it? So, I think they have to improve in that. So, like in Life Sciences you have to like engage the content to get it, because it's very hard. It's a hard subject, so you have to know what you're really doing. So, if a teacher can teach a content and after the lesson, they give us questions that we have to like, answer or write on, I think it would be good. Everything will be perfect. Yeah.
Interviewer	So, more activity based?
Participant T	Yes, more activities.
Interviewer	Okay, participant J?
Participant J	So yeah, I just think it would have been a lot more beneficial if lecturers tried to engage with us during lectures, during like how they would during a contact lesson where they would ask a random student a question and so on and answering it. I think all that was missing for me is just that element of engagement.
Interviewer	So, less talk and chalk, more engagement?
Participant J	Yeah.
Interviewer	Okay, and participant R? I think you kind of told me what you think your lecturer could do better, but do you maybe want to add on to that.
Participant R	No, I'm still leaning on that one for interactive lessons.

Interviewer	Yes, okay. So, you prefer live interactive classes. When your teacher was teaching you guys live, do you think that he or she could have improved their teaching strategies in any way?
Participant T	Sorry, can you please repeat the question?
Interviewer	Oh, that was for Participant R. So, when your lecturer was teaching you guys live, do you think they could have improved on their teaching strategies in any way, if you can think back? Participant R? Okay guys, I'm going to move on. Okay. So, I've asked you questions now about your experiences of learning Life Sciences online, and I'm going to ask you about what teaching strategies should be used to teach Life Sciences on online learning platforms in schools. In schools specifically, remember they are a lot younger than you. So, what teaching strategies do you think should be used to teach them Life Sciences online? Who'd like to go first? Participant J?
Participant J	So, I think a lot of the emphasis when dealing with younger children, well, not just younger children, teenagers as well, it should essentially be focused upon the questioning tactics that brings you into the class. So, obviously we're dealing with a lot of misconceptions. So, they should probably start with questioning tactics to see where the class stands with that particular topic and then they can start using any, really any teaching strategy that they are comfortable with. They can start online work, because it's important that… (unclear)

	So essentially, it's more focused on the questioning tactics that the teachers use to engage online, because engagement on online learning is very difficult, because it's tempting to learn with the camera off and start doing something else. So, it's just important to keep learners engaged.
Interviewer	Yeah. Okay. Thank you, participant J. Participant T, participant R, what teaching strategies do you think should be used in schools when teaching Life Sciences online?
Participant T	I think uh simulations are very helpful when you're teaching Life Sciences online.
Interviewer	Yes, that's interesting.
Participant T	Yeah, I still dwell on that because uh simulations like, you use cartoons or other drawings or other things like you can demonstrate some things. And I think that's going to be interesting to learners because learners want to learn about something that is interesting. The ones who learn more than a teacher just telling them this is happening in this, the process is happening like this. But if they see it happening in that simulation, they'll be more interested to learn more. And that will drive them to go even on YouTube, on Google, on other websites, to learn more about that particular topic. So, I think they should like promote the use of simulations online.
Interviewer	Yes. Okay, that's interesting. Thank you, participant T. And participant R?
Participant R	I'm supportive of participant T. Yeah. The use of visuals for example.

	For example, myself when I maybe when I watch Muvhango, then someone asks me later and says: “What happened on yesterday's episode from Muvhango?”, I will explain everything in detail. So, I think the pictures are more better than just written words.
Interviewer	Okay, okay. So, both you participant R and participant T agree that there should be some sort of visual stimulation?
Participant T	Yeah, because I think you can never forget what you saw than what you heard. You can hear something, but if you didn't see it, it's easy to forget. But if you saw it and even wrote down something about it, you never forget it, I promise.
Interviewer	Yes, that's true. And you actually get me thinking about different learning styles, catering for different learning styles on an online learning platform.
Participant T	Yeah, yeah.
interviewer	Yes. So, you bring up an important point. Thank you. Okay, and why do you think these teaching strategies should be used when teaching Life Sciences online? Participant T, participant R, why do you think it helps to have something visual when teaching online?
Participant T	Life Sciences is a practical subject, and we all know that. Everything a theory has a lot of what I can say, hypotheses that has to be proven. So, if you use uh simulations so that people know how this is happening, it will be easier for other learners to understand, okay, this is really happening, it's like this and it was proven to be true. So, it's a science subject and it has to have uh investigations, demonstration, uh practical work, experiments and everything, so yeah.

Interviewer	Yeah. And when you say simulations, do you mean visual aids? What do you mean by the word simulation?
Participant T	Simulations like the makeup. How do I explain this? It Okay, let me give you an example with electrical circuits. You can use it so to create… Okay, if the volt is like this, the bulb is like this, the resistance is like this. You can use the simulation just more like a visual work.
Interviewer	So, like building a circuit online?
Participant T	Yes, you can do that using simulations. It's more of a visual work that is not done by a person, like physically done. It's done online.
Interviewer	So, you're trying to replace what you could have done in person with something online.
Participant T	Yes, because now we are talking about online learning. So, if I can't be in class then the computer will do the things for me.
Interviewer	Yes, yes, exactly so that's a very important point because when you're teaching online, you need to utilise tools that you have.
Participant T	Yes.
Interviewer	Yeah. Okay, participant R? You want to add on to what participant T said?
Participant R	No, no, no.
Interviewer	Okay, participant J? Why do you think there should be more engagement or interaction?

Participant J	I think I explained it somewhat. What I've noticed during COVID, the pandemic is online school doesn't really… (unclear) and so like when you get into the swing of things, realistically, not that they're going to pay much attention because it comes with a level of agency that not a lot of people have, and especially in high school. If students are given that level of agency, they might not realize that what they're doing matter and may just ignore it. So, it's important that we keep them engaged. And also why I mentioned questioning tactics, also just because there's a lot of misunderstandings especially in earlier years. There is common terms in many different science subjects so we need to like, get rid of misconceptions.
Interviewer	I agree. Thank you. Okay. So those were questions about teaching strategies, and I'm going to move on to what we call representations, which some of you have already touched on in your answers. So, representations are things like visual aids, experiments, even demonstrations that can be used when teaching online. So, keep that in mind. So, the next question. What representations did your lecturers use when teaching Life Sciences online? Again, representations are things like visual aids, experiments or demonstrations. If any what representations did they use? Yes, participant J?
Participant J	What I can recall is, just some visual aids, although outside of our lecturers for assignments, they had us use some online experiment stuff where I'm not sure what it's called, but it's

	something where you can play with circuits. They made us make use of software like that. Other than that, I only think we made use of visual aids.
Interviewer	Can you elaborate on visual aids?
Participant J	Just like diagrams and images and sometimes video.
Interviewer	Okay, by the way, the circuit building thing, I actually know what it's called, it's called PHET.
Participant J	Okay, PHET.
Interviewer	Okay, participant T?
Participant T	I've seen a lot of uhm, PowerPoint presentations. So, the lecturers use PowerPoint to present information because that that's a part of the Microsoft platform that you can use to create simulations, cartoons, experiments. You can use that platform to create a lot of things that can be appealing to the students or to the learners. So yeah, they use PowerPoint to represent information. For visual learning yes.
Interviewer	Yes. And then you also mentioned the circuit building and stuff.
Participant T	Yes.
Interviewer	Okay. And participant R? What representations did your lecturer use when teaching Life Sciences online?

Participant R	Uhm, she used the slides and some videos which she uploaded on ClickUp for us to watch. Yeah. I think during the we supposed to do an assignment for I think practical examination. We're designing a practical examination. So, she she recorded a video and uploaded it on ClickUp and then we went there and watched the video and then designed our practical examination.
Interviewer	Okay, what was the video about?
Participant R	Uhm we supposed to design a practical examination which includes uhh 5 stations and then each station should have uhh one or two questions. And then learners was supposed to spend not more than five minutes answering the questions of each and every station, so the practical exam was supposed to be out of 20 marks.
Interviewer	Okay. And how did that video prepare you for it?
Participant R	Uh you know very effective, it was very effective.
Interviewer	Okay. And what was the video about? Did she do a practical demonstration in it or did she just give you instructions?
Participant R	Ohh she did the the practical demonstration and also give us the instructions.
Interviewer	Okay. Okay, that's interesting. Okay. Thank you. And were these representations effective in other words, did they help you learn?
Participant R	Yeah, they have.
Interviewer	Okay, participant R first.

Participant R	Yeah, they help me learn.
Interviewer	Okay. Thank you. You don't want to elaborate on that?
Participant R	No.
Interviewer	Okay, thank you. Participant T?
Participant T	Yeah, it did help me because okay, from the past I didn't know that you can use Microsoft options to to create something wonderful. So, we being able to learn using Microsoft PowerPoint and YouTube videos. All those slides was so impressive to that. I I wanted to learn more, wanted to attend class like every day so I can see those visual things you get what I'm saying. So yeah, it was very effective and helpful to me.
Interviewer	Okay. Thank you and participant J?
Participant J	Yeah, yeah, I would say they were also helpful. They were very good visual aids. Yeah. I don't really have much more to add or anything. They helped clarify concepts.
Interviewer	Okay, perfect. Thank you. What representations do you think could have worked better or what representations do you think your lecturer should have used? Okay, who would like to go first? You are welcome to take some time to think. What representations do you think could have worked better? Yes, participant J?
Participant J	Maybe using the relevant experimenting software in class, but other than that, I think the representations, what they did were supposedly real.

Interviewer	So, experimentation software. Okay, thank you. Participant T, participant R? What do you think could have been done better? In terms of the use of representations, remember representations means visual aids, experiments or a demonstration.
Participant R	Although they were able to to to include as many information that they can. I think in terms of investigation they were lacking, so there were not much investigative videos in the lesson like we had only few. So yeah, they can just improve on that and then include as many many informative videos that they can about experiments and investigations.
Interviewer	Yes, you're right. Experiments and investigations are a big part of Life Sciences. Uhm, what representations specifically do you think they could have you for investigations and experiments?
Participant T	I think they should just make videos of them making the experiment, even if it's a simulation, explaining how this and this came to be about that, how this happens, when it happens. Okay, let's take an example about the boiling point. On how they work, how did they the the boiling point was reached? and everything that should just make video showing us step by step processes of how it happened with temperature make sure what's the boiling point range I mean.
Interviewer	Okay, so like a video demonstration?
Participant T	Yeah, they should do more demonstration in the videos.

Interviewer	Okay, thank you, and participant R, what do you think your lecturer could have done better in terms of representations online?
Participant R	I don't really have any. Sorry, ma'am
Interviewer	Okay, no problem at all. Okay, next question. Now I have asked you guys about your experiences with the use of representations online Life Sciences, and now I'm gonna ask you guys about what you think should be used in school. So what representation should be used when teaching Life Sciences on online learning platforms in schools? Okay, bear in mind, school, high school. Who would like to go first? Yes, participant J?
Participant J	I think the same ones can be used because this PowerPoint slides with diagram videos and the relevant experimentation software or videos as well. You can use. So I don't think there needs to be a difference.
Interviewer	Okay, thank you. Uh participant T, participant R?
Participant T	Uhm I still say the same thing. But, because these high school students or learners, I think there are so much social media active. So, I think we can also use some of the social medias that they are using to put this information there. So, one day when they scroll, they find, oh this is what was in my class. So, I think we can also include social media in their learning because they're so active. They, trust me. Yeah.
Interviewer	And how do you think social media and online could go hand in hand?

Participant T	Because learners, stay online for, for social, for social gathering, for social meeting with their friend, why can't they stay on social media, to study or to do something academic related? So yeah.
Interviewer	That's very interesting insight. Okay, participant J has his hand up.
Participant J	I had weighted that it would actually be a negative thing, putting content on social media because obviously students go on social media platforms, to get away from their academic content. For example, if I was scrolling through Instagram after studying and then I see my education psychology slide, I'm going to leave, and then I'm going to go into the classroom slides. Laughter Maybe we should… I'm not entirely against the idea of using social media. Perhaps it is something that would have to be discussed with the students, like what platforms are not just going to invade your space like I know that a lot of people don't really use Facebook for socialising anymore. So maybe that they can make a Facebook page for the class and those things there.
Interviewer	Yes. Okay, so since you guys brought up social media, to what extent do you think social media could be incorporated into education?
Participant T	Only if it's academic related, not because they want to chat with their boyfriends or their friends about gossip and everything. But I I I I get what participant J is saying. Ohh. Okay if I see something about my module or my subject online. I'll probably just skip it. But I think curiosity will allow you to go there and see what's happening. I'm I'm a curious person. When I see something about my module or subject online I go in there to see what's going on. If it's not interesting I'll just pass by.

	If I see all of my friend there, I will literally stay and say, OKAY, if my friends are here doing this, why can't I? So I think it can. It depends on what kind of mindset you have. Like mine. I'm I'm a curious person and I can't let another rain on my parade if I want. If my friends are learning, why can't I learn?
Interviewer	Yes, so it's good motivation in that sense.
Participant T	Yeah, it has motivations.
Interviewer	Okay, participant R, I see you have your hand up.
Participant R	Uhm we can use social media to communicate with our learners. For example, we can create WhatsApp with where we communicate with them daily, maybe give the exercises after school. And then ask them to bring them tomorrow so you can use them for communication between the teacher and the learners
Interviewer	Yes, yes, that's a good answer because I asked to what extent should we use social media. So you say like for communication purposes.
Participant T	Yeah, I agree with participant R because if even at high school we had group chats where a teacher will be a group admin. No, no inappropriate things are sent on the group. We just like communication: “Okay, today no school, today we are attending at 6 o clock in the morning. Today we have assignment due, you please don't come with your phones or bring your phones at school because there are videos that you have to watch this and this. Yeah. So like that's helpful. Participant R was saying I yeah it's very very relatable.
Interviewer	Thank you, participant T. Yes, participant J?

Participant J	So I actually last year, for my faculty house, we had a panel discussion where we briefly talked about online education and one of the people who were a panellist was this online influence. So, a social media teacher. So, what he would do is he would always record his lessons and post them there as well. So I think maybe… So people have to be active with the content. So I think maybe that's something that we need in the classroom per say.
Interviewer	Yeah. Okay. No, that that's a very good insight from you guys. But since we're on the topic of social media, how could we specifically integrate social media into Life Sciences online education? Specifically for Life Sciences
Participant J	So I'm like recalling content I have from life science. Uh, and in high school, there's a lot of memes. laughter I know evolutionary like when we learned about evolution there's this one meme of a T-Rex turning into a chicken overtime and it's like evolution! What are you doing? Evolution! Stop!
Interviewer	I think I've seen that one.
Participant J	So I think memes are a good way to like keep students interested.
Interviewer	I think so, definitely, humour and education definitely goes hand in hand. Yes, okay, participant T, participant R?
Participant T	Uhm well, my side. I think that we can use social media in science related issues because if you are conducting investigation interviews, you're gonna use social media to research more about science through people. Example, what you have done, you use a WhatsApp to communicate with other students about your research in Life Sciences. So I think if you want to get more

	information you can use social media and you're gonna find it there.
Interviewer	Yes, yes definitely. Good example. Thank you, participant T. Participant R, would you like to add on anything?
Participant R	Uhm I can use social media to. Exchange maybe life science question papers.
Interviewer	Yes, okay. Sharing content. Perfect. Thank you. Why do you think these representations that we just mentioned, social media together with other things, should be used when teaching about Life Sciences on online learning platforms? Okay, so before social media think about what you guys mentioned, why do you think we should use these? Participant T, I see your mic is on.
Participant T	Yeah, they help in describing, uh, topics very well. They are very descriptive when you when you give information in class, you can usually use videos for students to see what's happening. As I said before because. You cannot forget what you saw. So then if you are using this representation, student won't forget. They are very useful. And then nothing. What was I I wanted to say something I forgot. Let me remember.
Interviewer	No problem. Participant J can go first.
Participant J	Yeah. So I think it's just good in general to use some notes for different arrays to communicate the same content, for example, not everyone is going to get what you're saying. Well, it's topic if

	you just use the slide. You can also make use of diagrams and pictures that show the process, or videos, because some people explain topic better than other people. I know in the Life Sciences classroom in Grade 11 I had difficulty understanding what's going on. But then when I go to YouTube and type in crash course of amoeba sisters, suddenly I understood what I am studying. Yeah, it just. It's generally good to involve multiple different formats.
Interviewer	Yes, different representation represent the same content differently. Okay, thank you. Uh, participant T?
Participant T	Yeah, I remember what I wanted to say is that we this representation help in in Life Sciences because Life Sciences is a very disciplined subject. Yeah, we know that. So if a teacher will be used things, they'll be. They'll be able to prepare. Materials that they're gonna be using in class step-by-step. Okay, I'm gonna show this to the learners. How am I gonna do it? Which slide go first. Which one goes last? Which videos I'm gonna show to learners? You even you're you're able to construct everything. Yeah, in that representation, in a small in a small video. So you're able to fit as many information as you can so that learners can be able to understand more information in a small time or limited time, yeah.
Interviewer	Okay, thank you. I see we lost a participant, but that's okay, we'll keep going. Uhm, so now we've covered teaching strategies online, we've covered representations online. Now we're just gonna cover any other sort of digital educational technology that can be used online. So my next question, how should other digital educational technology such as tools on the online learning platforms for example the chat function, the video camera, the presentation

	tools, how could those tools be used and integrated into Life Sciences lessons on online learning platform in schools?
Participant T	Please repeat the question.
Interviewer	So we have covered teaching strategy and representations, okay. Now think about the other digital educational technology that we have available on online learning platforms such as the chat function. We have a video camera and we also have lots of other presentation tools that I'm sure you've come across during your experience with learning online. How would you integrate those digital educational technology tools into Life Sciences lessons on online learning platforms in schools? Yes, participant J?
Participant J	So, a lot of what we can do on online learning platforms emulates what we can do in normal school functions. For example, instead of having them write on the chalk board you can say type the answer on the chat function or you can even like call them to the front and ask a specific student please write what you think on the slide itself. You can use that function. Yeah, it's functions like that. Of course, there's also breakout rooms you can make use of. So, get the students in discussion on more things that are debatable. Like at the end of grade 12, yeah. And other topics have breakout room. I think a lot of this comes with researching the platform, finding out what things you can do, because a lot of people just think it's like virtual classrooms, but there are things you can do on like Blackboard that you can't do in a normal classroom.
Interviewer	Definitely, so you gotta utilize it to its full potential. Okay, participant T?

Participant T	Yeah, I agree with with what participant J said. a chat box for me, a chat box. I can be useful after a lesson after a video lesson so that they can be able to type down the questions they have. Or if I ask a question on that video they will be able to type them down on the chat box so that can be useful in terms of typing the answers that doesn't require them to speak or being visible in the video or in the project. So videos can be useful if I give the learners certain projects to do something, and then we'll have to create a video of something or their experiment or whatever they're doing. So yeah, they can be used in a lot of things in Life Sciences, Life Sciences is very complex, but disciplined. So they can be used in many phases of learning Life Sciences.
Interviewer	Yes, okay. And why do you guys think the digital educational technology that you just spoke about should be used and integrated in this way when teaching Life Sciences on online learning platforms? Why yes, participant J?
Participant J	This goes back to the one thing I've been ranting about this whole session, engagement. Its just more ways to get students to engage.
Interviewer	Perfect. Thank you. Participant T?
Participant T	Yeah, it creates participative learning, learning environment learners will be able to type down the answers without having to talk. Some of us uh stutters, we do stutter naturally. A being able to type down and answer is very helpful to some of us because we don't have to speak the confidence that we have when we type that we type down answers. It's not the same as when we speak. So a chat box will be helpful in that and a video it.

	It doesn't necessarily mean you see you have to stand in front of a video, you can just. Show around or maybe a bit of your face talking, not you don't have to do anything more. So yeah, this thing are gonna be helpful when you want a class to participate because there will be a lot of confidence that will be shown in class.
Interviewer	Yes, definitely. Okay. So we only have two more questions to go and then we're done. How important do you think is the role of digital educational technology in online learning for Life Sciences in schools? How important?
Participant J	I think the role of digital educational technology is very important, especially because now we are rapid, well not areas in South Africa, but some areas are getting more technological like it's so many schools I know shifted to online learning. So I think it's important that we start in learning how to integrate technology where we can. However, we must, the curriculum must not be changed because until every classroom in this country has the same technology. We can't really make this the standard. This is something that's beneficial to those who can have it. But the curriculum must still be designed for those who can't have it.
Interviewer	Yes, that's very important. Thank you. Participant T?
Participant T	Please repeat
Interviewer	Sure how important is the role of digital educational technology in online learning in Life Sciences in school?
Participant T	It plays an important role because it is responsible for increasing the engagement of learners.

	If if we can look at it, learners engage more online than in person. So yeah, it helps. Let us engage more. It also help teachers improve their lesson plans. If you have noticed, teachers are more organized online than they are in class because of the nerves. Ohh, as I said, the confidence the eyes. You know learners can make you feel confused or or feel like you don't know what you're teaching. So you must get to be so organized. Have the Lesson plan. They also have to show off their skills on line, what they know, tell more, tell the learners more about their researches online, because learners would be interested, obviously because online platform is the only thing that they'll be using in time. But. So you see there will be more participation in class. Engagement. Because of the educational technologies.
Interviewer	Okay. Thank you. So last question, is there anything else regarding teaching Life Sciences on online learning platforms at schools that you would like to mention that maybe I haven't covered yet?
Participant T	What?
Interviewer	Anything else about teaching Life Sciences on online learning platforms at schools that you would like to mention? Anything else that I haven't mentioned yet? Okay, participant T, you may go first.
Participant T	Men before. You can go first.
Interviewer	Okay, participant J?

Participant J	This is actually something we've been doing in one of my classes recently online and I think It's the responsibility of a teacher when they know their classes online should not just keep the learning in the classroom. So for example. There are many apps that a teacher can integrate into their learning style and they can make an entire learning environment. for example. Discord, I find is a good free app that you can use for creating an educational environment online. That's a lot less data expensive than the blackboard collaborate and others. so teachers can use this discord. To create quizzes, make an entire chat room for learners to discuss a topic. So I think it's just the responsibility of the teacher to. Look for alternatives to make it more accessible, but still engaging environment for learning, not just outside of the classroom to encourage them to do more than they're required.
Interviewer	Okay. That's very interesting. Thank you, participant J. Participant T?
Participant T	On my side, I certainly feel like. It helps learner's becoming in becoming flexible, or teachers teaching flexibly. So what I'm saying is that you can be able to teach, okay, let's say it's a live. It's a live. Class. You'll be able to teach the learners if some of the learners have issues or they're sick, they're in the doctor or they can't attend. At that moment, they'll be able to retrieve the recording of the lesson, which is very helpful. Other than in contact in contact those. There's no recording. the teacher is teaching on the White Board or a black board? Whatever they're using in class and then you won't get any information about the previous lesson other than your your peers

	telling you we did this and this in class, which is confusing. So I just want to say that online platform as much as. As it seems a hard to to adjust into, it is very helpful in many ways because you get to catch up with a lesson with the lecturer with the content using the recordings that was recorded in the previous day. Other days, even in a in the past month you can able to to see that recording.
Interviewer	Definitely. So yeah, you have access to the content. Even after the lesson has taken place because of the recording. Yeah. Okay, guys, just one more thing before we go. Anything else you want to mention about teaching Life Sciences online like specifically Life Sciences online? Is it different to other subjects? Would you do something differently?
Participant T	I just. I just wanna say that specifically they should just include more and more videos of experiments because some of the experiments we do, the experiments, we don't do them correctly and then we end up recording incorrect data and end up having wrong information about that experiment. So I think they should do a lot in a lot more of experiment, investigation, practical work as a whole. So that when we are doing this certain practical investigation or. Experiment. We are able to look for an alternative in those videos of Life Sciences, yes.
Interviewer	Okay, thank you. Participant T, participant J?
Participant J	Don't really have anything specific from my side. I tend to think of teaching as a whole.

Interviewer	Yes. Yes. Okay. Thank you very much for your time that I really appreciate it. And I think I've gotten some very detailed data from you guys. Thanks for your insight. I really appreciate.
Participant T	Thank you. Bye.
Interviewer	Bye participant T. Thank you.

Focus group 3

Interviewer	Okay, recording. Okay. Hi everybody, thank you so much for joining me for this focus group interview today. A little bit about my research is, I'm loOkaying at Life Sciences student teachers' perspectives of learning Life Sciences modules online and how you think Life Sciences should be taught online in schools. So, first question: "Do you think that Life Sciences could be taught effectively in schools using online learning platforms?
Participant	I believe so, but not purely online. More like a hybrid type situation. Because, otherwise, children are just going to distance themselves, or not gonna interact at all.
Participant	Yeah, I'm not a fan of the online thing at all, because I'm teaching now Maths online and Natural Science, but the children is not doing well. And Life Sciences is very practical. You want to touch the stuff, you want to see it, and online is not that interactive. So, I think it won't be that successful, only online.
Interviewer	Yes, and I agree with you. Life Sciences is a very practical subject. So, how would you go about teaching it online? And, what do you girls think? Do you think Life Sciences could be taught online effectively?
Participant	I think the only time Life Sciences will only work online is when you just give learners group work or assignments. In that way, online, it will work. But, when you have to introduce a topic, you need to be face to face, in contact with the learners. See where they are struggling. Make sure they understand. But, online assignments are just easy, because they can also research, uhm, find out more information on their own and also there's a website that helps with making quizzes. Quizlet and Kahoot. You can actually put a topic, like

	Meiosis, and it will generate questions for you. So, in that way. Learning Life Sciences online, it becomes much easy. Because Life Sciences has a lot of content, so it helps for learners to prepare themselves, know where they are struggling and what's new.
Interviewer	So, you guys have given me two different perspectives. You were looking more at the practical side of things and you were Looking more at the content side of it. And, tell me a little bit more about the group work. Uhm, you said something about group work.
Participant	So, with group work, they can use platforms like Zoom. Each individual will do research on their own, then share information amongst themselves. Because, I believe I learn best when I am with my peers than when I'm with the teacher. When the teacher is explaining, I can get some information, but with my peers I feel like I can relate. I understand them better, so when we discuss, that's when I'm like: "oh, I understand that, oh, Okay!".
Interviewer	Okay, that's interesting. And, you girls want to add on anything to that?
Participant	Uhm, for me, I don't prefer online. Compared to how things were like before, writing here at campus, my marks before… like now they are much better compared to then. So, I feel like contact is much more simple.
Interviewer	Okay, so based on that experience, do you think that Life Sciences could be taught online in schools?
Participant	No.
Interviewer	No, and you're also on no?

Participant	No, it can't be taught online.
Interviewer	Okay, so to just get a brief answer, most of you say no, or yes?
Participants	No
Interviewer	Okay anybody else?
Participant	A combined approach.
Participant	Yes, a combined approach.
Interviewer	So, we've got about 3 nos, 1 yes and 1 hybrid?
Participants	Yes, yeah.
Interviewer	Okay, cool. That's interesting. My next question was going to be to briefly explain why, but I think you guys have already covered that. So, the next set of questions is all about teaching strategies on online learning platforms specifically for Life Sciences. So, the first question there: "What teaching strategies did you lecturers use when teaching you Life Sciences online?".
Participant	I didn't see anything. I haven't seen anything
Participant	Personally, I feel like I taught myself Life Sciences. It was just self-study. (Everyone agrees)
Participant	It was so boring. Like, you can't attend the whole lesson. They put us to sleep.

Participant	They said, okay we're going to be online and then they did the online thing. Then, you just go on, on your own. It's just them talking to themselves, and then some questions. But some lecturers even ignore the questions.
Participant	They just go through the slides. They are reading the slides, they don't teach. That was not good. (Everyone agrees)
Interviewer	So, what I'm getting from this is your lecturer would just project slides and read from it.
Participant	Yes. Nothing was taught.
Participant	Not all lecturers, but most of them.
Interviewer	Okay, and specifically for Life Sciences?
Participant	Yes specifically. Like ZEN and BOT, we did it last year. MLB, yeah, they were only reading the slides. GTS.
Participant	GTS, you had to do your own math. You had to do it on your own.
Interviewer	Was there any Life Sciences module that maybe stood out from the rest of them? Where the teaching strategies were a little different from the others?
Participant	No. Firstly the slides are just suhmaries. So basically they are just highlighting the important concepts. The rest of the work, you just have to do it on your own. So, basically you are teaching yourself the subject.

Participant	But, even if you can read with those slides, the questions on the test and exams, they are way too different.
Participant	It's like JLS that we wrote, he makes basic slides and then he's just talking in the air. Then you have to write everything down. You're more focused on writing down the precisity of what the lecturer is saying than actually taking it in and understanding the concept.
Interviewer	Okay, so, based on that, would you say that these teaching strategies were effective? In other words, did they help you learn?
Participants	No.
Participant	Well they didn't help with learn, but they helped with time management and research. The positive thing is they with the online learning it taught us how to learn ourselves and ultimately as teachers this is what we're going to do.
Participant	Yes, that's true.
Participant	We're going to learn ourselves then we have to teach the children. So it's actually beneficial but not at a specific time.
Interviewer	So, you learn certain skills, but there were some things that…
Participants	The content though. We struggled with writing tests or knowing the content, because they kind of left us hanging. But yeah, the other skills are time management, researching, those things we are good at.
Interviewer	Okay, that's interesting. So, what teaching strategies do you think could have worked better?

Participant	More visual stuff. Or more interactive, like doing polls constantly throughout the lecture. I know with our ZEN lecturer, the lecturer tried to do that. And it helped, because he asks us previous knowledge and then we did the class and then he did a revision type of “what did you learn now?”. And that was like Okay, now I need to stay online, because I need to get those questions so that I can screenshot them for the test.
Interviewer	Okay interesting, and what about you guys on this side? What do you think could have been done better in your Life Sciences lectures in terms of teaching strategies?
Participant	More detailed slides and more videos.
Participant	I prefer when we had to loOkay for the answers for ourselves.
Participant	The videos were very nice.
Participant	Sometimes when we asking questions, the lecturers should give us more clarity, not like a clue. Because, they only give us a clue , then we have to find more detail for ourselves.
Interviewer	Okay, interesting guys. Now, so, that was based on your experiences of learning Life Sciences online. Now I am going to ask you guys about what you think should happen in schools. So, what teaching strategies should be used to teach Life Sciences online in schools specifically?
Participant	I would say a lot of quizzes, because like being a student now, I didn’t know what’s going on. Then just before exams I would study everything and write exams on it, I forget. So, we weren’t tested enough to see Okay: “Do we understand it? Do we know our work?”. So, yeah, I would say a lot of quizzes, a lot of polls, tests. Not let them

	count, just do it to see if the students are with you, because online you don't know, the shy students never speak. You don't even know you have shy students.
Participant	Yeah, and when I was in school, we had Life Sciences and you had your quarter test and then that was the only test you had and then you're only going to write about the work in the exam and that was it. There was no… and maybe a practical, which I did terrible in because I didn't understand the work.
Participant	So, online is a great place to do quizzes to see if they are with you.
Participant	Because it's self-marked. So, the teacher doesn't have to worry about the time to mark and give feedback on that.
Interviewer	Okay, interesting. And what about you guys? What do you think teaching strategies should loOkay like when teaching Life Sciences online at schools?
Participant	I think the teacher can use videos. Just to explain things that you cannot explain in class, because some content needs you to elaborate. The learners need to visualise. So, videos will make it easy, make them have a better understanding.
Participant	It helps them to engage.
Participant	Yeah, we need engagement.
Interviewer	Okay, and you two? Do you want to add anything onto that?
Participants	No. Videos and the quizzes will work alright.

Interviewer	Okay. That's interesting. And why do you think teaching strategies should be used this way when teaching Life Sciences online? I think you guys did cover some of that, but lets add on a little bit.
Participant	It makes it more enjoyable.
Participant	You don't only stress about learning, but you also get to interact. So, its easier for you to remember and call like, actually memorise, Life Sciences is a memorising subject, so having quizzes, game boards that have Life Sciences content will make learning fun.
Participant	Yeah and like with the videos, like with my students at the beginning of the year, I showed them how you attach lungs to the machine and then it pumps. So, that's nice stuff you can use. And that's making it visual.
Participant	And it can be in videos.
Participant	I used a video, yeah. So there's enough resources to do it.
Interviewer	Okay. So that was basically about teaching strategies online. Now I'm going to ask you guys about representations. Now representations is actually a Life Sciences term, so it refers to teaching aids that we use to help us teach, for example, it could be things like visual aids, experiments or even demonstrations. Okay, those are the things that we refer to as representations. So, what representations did your lecturers use when teaching you Life Sciences online?
Participant	The laser.
Interviewer	The laser? What's the laser?

Participant	It's just a laser thing, that as they present. I know it's stupid, but it's all going to link up. As they present the PowerPoint, they just put the laser on then they can draw. Or the drawing tool.
Participant	Yes, on the whiteboard. That's it.
Interviewer	Okay, PowerPoint presentations could also be a representation and I know you mentioned that earlier.
Participant	But, not just plain PowerPoints. The one with recorded voices, I think they are much better than just playing the PowerPoint slides.
Participant	Then those links for videos, maybe from YouTube, count as that?
Interviewer	Yeah, definitely, it does.
Participant	Which subject was the recorded voices again, on the slides? I can't remember.
Participant	I don't remember, but we once had a module like that and it was very helpful, because as we are reading, the lecturer is actually explaining what the slide is actually talking about. It's more detailed.
Participant	It was an OPV subject.
Interviewer	So, was that done live or…?
Participant	No, you just upload it as PowerPoint.
Participant	It's a slide that you upload a voice recording of what that slide is about. So, it's you highlighting… So, the slide is just highlighting the keywords that you are explaining what that means.

Participant	Listen while you're watching.
Interviewer	Okay, that's interesting. That's what we call an asynchronous approach to online education. It's where the teachers will put up material for their students and then the students can go through it whenever.
Participant	So, I like that approach more than the online one.
Participant	Yeah, more than the online one. It's more like the same thing.
Participant	It's online but more beneficial than class.
Participant	Yes, and I can stop and think about my answers.
Participant	You can pause for yourself.
Participant	Or google a word you don't know the meaning of. Yeah, it's very nice.
Participant	Yeah and you can spend your own time on it.
Interviewer	So, for interests' sake, when you have a live lesson we call it a synchronous approach. When the teacher just uploads material then we call it asynchronous, because it's not happening live. If that makes sense. Okay, so, do you think these representations were effective? Or, in other words, did they help you learn?
Participant	There was nothing for me special about it.
Participant	We are very harsh.
Participant	I liked the recordings, because…

Participant	The recordings was nice.
Participant	You still have to go through the recording again.
Participant	Yeah, I studied more effectively. I think if I were on campus and I sat in the lecture hall, I wouldn't have been able to write everything down, understand it and go back. So, yeah, that's beneficial.
Interviewer	And then we did speak about PowerPoints. Did you find that representation effective specifically?
Participant	Yes (all)
Interviewer	And then I think you guys did speak a lot about the asynchronous PowerPoint with the voice recording over. What would you say about that? Did that help you learn?
Participant	Yes, 100% (all)
Interviewer	Perfect. So, what representations do you think could have worked better?
Participant	Definitely. Well can you include, can I say, that they can include apps?
Interviewer	Yes, definitely.
Participant	Yeah, I would make use of apps. Yeah, because we all have computers or a cell phone to be able to join anyway so, give use apps or games or stuff to help us.

Interviewer	Elaborate more on apps. What kind of apps do you think could be used?
Participant	What we did in OPV, like Kahoots for example, quizlet.
Participant	Even the same thing that we did for Chemistry. Last year, what was that?
Participant	Oh, that was OWL. Yeah, the Chemistry where we did the 3D. Yeah, that was cool. And, for like my OPV, we used an app, Organs. So, it shows you internal organs in 3D. Yeah, internal organs and you can zoom in and out and move around. Because, that makes it exciting. Just listening and nobody doing any effort, no one wants to learn.
Participant	Even at GTS we did have something like that. We even had a textboOkay.
Participant	Oh yeah, we had an online textboOkay that had quizzes. Yeah, that was nice.
Interviewer	Okay, that's cool. That's actually a very interesting one. So, that was representations that your lecturers used when lecturing you Life Sciences. What representations do you think should be used when teaching Life Sciences online in schools specifically?
Participant	Definitely YouTube. YouTube, number one.
Participant	And then something like Kahoot, but you have to be smart about it, because not everyone has the resources. So, it's maybe going to be a group type of quiz Kahoot, that you have like three devices in the class. And it's three groups, because not everyone is going to have a device.

Interviewer	But, to suit that specifically to an online environment?
Participant	Oh yeah, then it will work perfectly. Because it's accessible on all devices.
Participant	Okay, anything else?
Participant	I would use also mind map apps. The students making a mind map while we go through the work. Or, requesting a mind map each week of the week's work. Or, if we are done with a concept then they have to suhmarise the work in a mind map, then they have it and I can go through it with them.
Participant	See where misconceptions are.
Participant	Yeah, and then they have the content to learn, They have suhmaries already. So, mind maps apps. Yeah.
Interviewer	And taking into account that Life Sciences is such a practical subject, what representations do you think schools should use to teach Life Sciences online?
Participant	That's a difficult one.
Participant	So I think if a school goes online, the school has to be willing to invest in some applications that they can give to the students. Because, we had an assignment that we had to find free apps and free something, like to do a hybrid learning approach. But I think if you're a school that is a hybrid or totally online, then they need to invest in that, because they're not paying for paper and textboOkays and things like that. So, they can buy Biology apps or something like that.
Participant	Yeah, which is of good content.

Participant	Yeah, which is better quality than the free ones.
Interviewer	Okay, that's a good point. That's interesting. Why do you think these representations should be used when teaching Life Sciences online in schools?
Participant	To make it not boring.
Participant	To engage the students.
Participant	And to... you can better explain. You can create an image for them to connect with.
Participant	Yeah, you have to replace the practical experience that you would have had in class.
Participant	With a visual one.
Participant	With a visual one that's equally as efficient, effective or even more so.
Interviewer	Okay, I agree, and you guys?
Participant	To make learners understand much better
Interviewer	Okay, perfect. So, that was all about representations online. Now, I'm going to ask you guys about other digital educational technology that we maybe haven't covered, maybe you are thinking about something that hasn't been mentioned yet. So, how should other digital educational technology; for example the tools on the online learning platforms, for example the chat function, the video camera and even the presentation tools; how can those things be used and integrated into Life Sciences lessons on online learning platforms in schools?

Participant	So, I would firstly say that the students need to have their video on, because otherwise they're not going to be there. And you can see if this person actually knows what's going on, because most of the time you can see on a child's face, nothing, he's taking nothing in. and then you need to be able to change it, even in an online setting. You need to change it to make it something interesting, to gain their attention.
Interviewer	Okay, so video cameras. What else?
Participant	The chat.
Interviewer	The chat?
Participant	Yeah.
Interviewer	Okay, explain a bit more.
Participant	So, when the lecturer is lecturing the learner can be able to type in a question which they don't understand.
Participant	Yeah, because what we found or what I found is in an online setting with my online learning, I was more willing to type in the type box a question than I would have been to ask directly. Because I'm very shy.
Interviewer	As opposed to switching your mic on?
Participant	Yeah, because the mic is terrifying.
Interviewer	Yes, that can help especially. What else? Can you guys think of any other digital educational technology? Any other tools online that could

	be used in schools to teach Life Sciences specifically? I'll give you guys a minute or so. Think out of the box.
Participant	Does it have to be online technology?
Interviewer	Mhm, specifically for online. Or something that you can incorporate into online
'Participant	No, sorry.
Interviewer	Never mind, let's move onto the next one.
Participant	Yeah, especially for Life Sciences, we cannot think of anything.
Interviewer	That's what makes it interesting, because it's a unique subject. Okay, so, the digital educational technology that you've already mentioned, why do you think it should be used and integrated in this way, when teaching Life Sciences online in schools?
Participant	Well, I think by the time we teach, for example Life Sciences online, it has been tested. So, these things we said, like the laser or the people putting videos and stuff, it has been done a few years so we can see if it works. And if it works, why not use it?
Interviewer	Exactly, and you guys mentioned the cameras and the chat function. Why do you think they should be used in this way when teaching Life Sciences online in schools?
Participant	Just for engagement.
Participant	Yeah.

Participant	It makes all learners to be comfortable with asking questions, even the shy ones.
Participant	Yeah, another thing is, I think if a student has his camera on, maybe he or she will be more willing to use the mic, because they see other students. It's not just this black screen with the lecturers audio going up and down. Yeah, so it's not so terrifying.
Interviewer	That makes sense. Okay, you guys want to add on anything to that? Anybody? Okay. How important do you think the role of digital educational technology is in online learning for Life Sciences in schools? How important do you think it is?
Participant	Well, there's not a lot of resources yet. If there are good ones, I think it's quite important. Because if you do any good stuff to replace a physical experience. So, it is important, but there's not a lot of it yet.
Participant	Yeah, and sometimes like in a contact class you don't have much resources. Like maybe in an online class you can play a certain video about somethings that you want to show up or something.
Interviewer	Okay, anything else?
Participant	From YouTube. Yeah.
Interviewer	Okay, and then the last question. Is there anything else regarding teaching Life Sciences on online learning platforms in schools that you would like to mention? Anything else about it?
Participant	One thing in the two times that we did our practical placements, both the schools that I went to had Google Classroom. And both teachers in different ways uploaded lecture notes or… how can I say?

	Content?
Participant	No. What the test is going to be about or announcements, or something like that.
Interviewer	Like a scope?
Participant	Yeah, the scope of the test. Everything was posted on Google Classroom.
Participant	Or District 4.
Participant	Yeah, now the learner is able to like go back to the content. Otherwise even if it's presented online, if they don't have the slides, they don't have the slides. But on Google Classrooms they can access the slides or contact the teacher. Yeah, because it has an email function or something like that.
Participant	The only thing that's difficult is… sorry I'm being negative about it.
Interviewer	That's fine, I want to hear all sides of it.
Participant	…about online teaching, is that you aren't there physically to help the children. Like, back to the Maths, but with Science it's the same, like the students is so far behind, because they weren't, they were too shy or weren't active on the online stuff. So, now they cant do what they are supposed to be able to do. So, it's very difficult to see which children needs help, which ones are too shy to ask. And if you get the marks too late. Then you must've already known who needs help. So, the online thing makes that a bit difficult. Because you can just disappear.

	The other thing is, in an online school if everything is online, you have to take into account the learners' social… like he's not seeing students. He or she is not seeing students. So, you need to create a classroom where they're constantly discussing and meeting new learners and everything, otherwise the child is going to feel like he or she is alone. Yeah, and then the understanding of the work is going to go down. And the motivation and the marks and everything. So, you need to take into account the social interaction that the learner also needs in an online environment.

APPENDIX 2: INSTRUMENT FOR FOCUS GROUP INTERVIEWS

1. Do you think Life Sciences could be taught effectively in schools using online learning platforms?
    a. Briefly explain why you think this.

Teaching strategies:

2. What teaching strategies did your lecturers use when teaching Life Sciences modules on online learning platforms?
    a. Were these teaching strategies effective and did they help you to learn?
    b. What teaching strategies could have worked better?
3. What teaching strategies should be used to teach Life Sciences on online learning platforms in schools?
    a. Why do you think these teaching strategies should be used when teaching Life Sciences on online learning platforms in schools?

Representations:

4. What representations did your lecturers use when teaching Life Sciences modules on online learning platforms?
    a. Were these representations effective and did they help you to learn?
    b. What representations could have worked better?
5. What representations, e.g., visual aids, experiments or demonstrations, should be used when teaching Life Sciences on online learning platforms in schools?
    a. Why do you think these representations should be used when teaching Life Sciences on online learning platforms in schools?

Other digital educational technology:

6. How should other digital educational technology such as the tools on online learning platforms, e.g., the chat function, the video camera and presentation tools, be used and integrated into Life Sciences lessons on online learning platforms in schools?
    a. Why do you think digital educational technology should be used and integrated in this way when teaching Life Sciences on online learning platforms in schools?
7. How important is the role of digital educational technology in online learning in Life Sciences in schools?
8. Is there anything else regarding teaching Life Sciences on online learning platforms in schools that you would like to mention?

APPENDIX 3: PROTOCOL LETTER

DEPARTMENT OF EDUCATION
Groenkloof Campus
Pretoria 0002
Republic of South Africa
Tel: +27 12 420 –XXXX
Fax: +27 12 420-XXXX
http://www.up.ac.za
Date

Letter of Permission: Pre-service Life Sciences Teacher

Institution: University of Pretoria

RE: REQUEST FOR CONSENT TO PARTICIPATE IN A RESEARCH PROJECT

Dear Student,

I, Alvira Prakash, am a Master of Education student studying through the University of Pretoria and would like to collect data at your institution for a research project titled *Teaching Life Sciences on online learning platforms: A phenomenographic approach*.

This study aims to discover Life Sciences pre-service teachers' experiences of learning Life Sciences on online learning platforms at university and how they think Life Sciences should be taught on online learning platforms in schools.

This study will make use of two focus group interviews of up to 20 participants each. The focus group interviews will be conducted either online or in person depending on Covid-19 lockdown regulations. If in person, Covid-19 protocols will be followed. The focus group interviews will be audio recorded.

The results of this study may be presented at conferences or published in scientific journals. If it is required, the researcher will be available to provide short presentations on the purpose, findings, and recommendations of their research to both GDE officials and the institution concerned. The pre-service teachers will be provided with letters that will elicit their informed consent and the researcher will only commence with data gathering once all these have been granted. Pseudonyms will be used to ensure confidentiality of participants.

We would also like to request your permission to use your data, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria and, where relevant, project funders. Further research may include secondary data analysis and using the data for teaching purposes. The confidentiality and privacy applicable to this study will be binding on future research studies.

Participation is subject to the Ethics Committee of the Faculty of Education at the University of Pretoria's regulations, and the following will apply:

1. The names of the institution and identity of the participants will be treated confidentially and will not be disclosed. All participants and institutions will remain anonymous.
2. The focus group interview transcripts will be treated confidentially. Only the researcher, Alvira Prakash, and the supervisor, Dr A.L. Abrie, will have access to all audio recordings as well as the transcribed data.
3. Only the researcher, Alvira Prakash, will know the real identity of the pre-service teachers who agree to participate in the study.
4. Pseudonyms for institutions and the pre-service teachers will be used in all spoken and written reports.
5. The information provided by the pre-service teacher will be used for academic purposes only.
6. Participation in this project is entirely voluntary. Participants have the right to withdraw at any time, and without any prejudice.
7. The pre-service teachers will not be exposed to acts of deception at any point in the research study.
8. The pre-service teachers will not be placed at risk of any kind.
9. No incentives will be offered to any of the research participants.
10. The decision to accept or decline the invitation will **not** have any adverse effect on the institution or the pre-service teachers.

The Faculty of Education and the Ethics Committee at the University of Pretoria have approved this study. For any further queries, you are more than welcome to contact the researcher or their supervisor.

Your support in this matter will be appreciated.

Alvira Prakash (researcher)
074 402 4479
u14090377@tuks.co.za

Dr. Mia Abrie (supervisor)
(012) 420 5569
mia.abrie@up.ac.za

If you are willing to participate in the focus group interviews, please kindly sign the attached form as a declaration of your consent. I would also like to request your permission to use your data, confidentially and anonymously, for further research purposes, as the data sets are the intellectual property of the University of Pretoria. Further research may include secondary data analysis and using the data for teaching purposes. Thank you for taking time to read this letter.

I, _____(your name only), hereby grant consent and permission to the researcher to collect data from me pertaining to the scope of the above mentioned research and to use it as specified in this letter.

....
Signature Date