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An investigation of how the lecturer promotes meaning-making when teaching cell biology to 1st year Natural Sciences pre-service teachers in an e-learning classroom on the BigBlueButton conferencing platform

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RESEARCH REPORT

An investigation of how the lecturer promotes meaning-making when teaching cell biology to 1st year Natural Sciences pre-service teachers in an e-learning classroom on the BigBlueButton conferencing platform.

A research report submitted to the faculty of Education (Science Division), University of the Witwatersrand, Johannesburg, in fulfillment of the degree of Masters in Science Education (MEd)

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DECLARATION

I, Nolwazi Mthethwa (1133058) declare that this report is my unaided work except where otherwise acknowledged. It is submitted for the degree of Master's in Science Education (Med) to the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted before for any degree or examination at any other University.

_____ MTHETHWA N_____

Date 04/09/2024

Nolwazi Mthethwa

Candidate.

DEDICATION

This work is the fruit of countless sacrifices. I dedicate this research report to my parents, my father Themba Petros Mthethwa, and my mother Zanele Gloria Mthethwa. Thank you for always encouraging me to pursue education and better myself. Thank you to my loving partner Tshepo David Sadiki for supporting me and encouraging me. To my beautiful son Leano, this is for you. To always know that even the sky isn't the limit, we crawled so that we could fly high.

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First and foremost, I extend my heartfelt gratitude to God for giving me energy, good health, and protection during the whole period of my study. It is only because of the grace and strength bestowed upon me by Almighty God that I was able to go through this program. Secondly, I would like to thank all the precious people whose encouragement and immense contributions have led to the success of this work.

Special thanks should go to my supervisor Dr. Caleb Mandikonza who despite his tight schedule found time to supervise my work, offering his tireless, assistance, guidance, support, and encouragement. May God richly bless him. Next, I thank my family, especially my parents and siblings, Khayelihle Mthethwa who encouraged and supported me during the whole period of my studies.

ABSTRACT

The past outbreak of the novel Coronavirus (COVID-19) greatly affected South African higher education which led to a complete closure of universities. The closure of universities has provided an opportunity for institutions to engage in their preparedness to use digital platforms. According to Mashau and Nyawo (2021), eLearning describes learning that depends on modern technologies to deliver students learning content. This study explored how the lecturer promotes meaning-making when teaching cell biology to pre-service teachers in an e-learning classroom. The study sought to find out which teaching strategies are useful to promote meaning-making in the teaching and learning of cell biology in an eLearning classroom. The study identified the teaching strategies that were used by the lecturer when teaching cell biology and examined how the lecturer used the teaching strategies to promote engagement which create an opportunity for meaning-making to be promoted. A qualitative approach was used due to its versatile nature when observing and interpreting human behavior and experiences. The lecturer was interviewed to understand the reasoning behind why he used the different teaching strategies. Data were collected from video-stimulated interviews and BigBlueButton video observations. Data analysis for this study was both deductive, using a thematic approach. The findings of the study established that the lecturer used question-and-answer, multimedia, and explanation teaching strategies across all the lectures observed, and the question-and-answer teaching strategy was dominant across the three lectures observed. However, different teaching strategies promote meaning-making differently. The findings also revealed that for the teaching strategies to be effective in promoting meaning-making in the BigBlueButton classroom, contextual factors such as class size and teaching and learning resources are important in making decisions on how to engage students.

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CHAPTER ONE

1.1 Introduction

The world is full of uncertainty and South African Higher Education Institutions have not been spared in their exposure to unforeseen events. The ability to put into use the advantageous opportunities of the fourth industrial revolution has been a challenge to many universities, individuals, and predominantly students. University graduates face a world that is transformed by technology, whereby different opportunities and challenges are created for formal education systems. The outbreak of the novel coronavirus has placed education on a pendulum (Makhlouf & Alani, 2022). The rapid and continuous changes we are experiencing today in technology have greatly impacted the emergence of sophisticated teaching and learning tools and systems that have a great impact on how students learn (Makhlouf & Alani, 2022).

Electronic learning is often abbreviated to eLearning. It can be defined as any learning activity supported by information and communication technologies (ICTs) (Wakasa, 2021). eLearning can also be defined as the appropriate organization of ICTs for advancing student-oriented, active, open, collaborative, and life-long teaching-learning processes (Wakasa,2021). This creates opportunities to expand the learning environment to cater to diverse learning styles, this is pivotal in meaning-making as this means that every student will be engaged during the teaching and learning process. This definition includes university-wide information systems that embrace blended learning so that students can benefit from the appropriate mix of teaching and learning strategies to minimize the constraints that may be posed by distance and limited resources. Different teaching and learning styles promote engagement which in turn promotes meaning-making. Teachers need to enhance student engagement through different teaching strategies as they improve active learning which promotes meaning-making.

In this research project, eLearning is defined as the use of Internet-based technologies by lecturers to provide students with access to learning materials; and interact with the content as well as other learners during the teaching and learning process. These teaching and learning opportunities are intended for students to acquire knowledge, construct personal meaning of the knowledge learned, and be engaged in the learning experience in the comfort of their homes.

According to Anastasiades andRetalis (2001), learning that is facilitated by electronic technologies can be either fully online or mixed mode (also known as hybrid). Fully online learning also known as distance education, refers to the delivery of educational content and instruction through the internet. It allows students to take courses and earn degrees remotely, without the need to be physically present on campus (Ashad, 2023). Hybrid learning combines in-person with virtual learning at the same time. That is, an instructor addresses both learners who are present with them in the classroom and learners who are at remote locations (Alnajdi, 2014). Thus learning is facilitated synchronously.

At the University of Witwatersrand, eLearning is supported by canvas “uLwazi”. The BigBlueButton is a component on uLwazi that provides a virtual space where students and lecturers discuss, interact, and share ideas and materials. The BigBlueButton is an open-source web conferencing system for online learning. The big blue button enables real-time and asynchronous communication between the lecturer and students. The lecturer can also track students' progress as they engage in online communication, provide feedback, and support collaboration through signposting.

In this research project, eLearning takes place as distant learning where the BigBlueButton is used as a platform for instruction. The lecturer’s role in this regard changes as they become expert questioners rather than providers of answers and designers of student learning experiences rather than providers of content. They provide the initial structure to a student’s work, encourage self-direction, and remain sensitive to the various learning styles.

That is, in this study, the eLearning classroom is fully online, and the BigBlueButton was used as a platform to deliver lessons and classroom interactions such as students asking questions and responding to the lecture’s questions occurred via the BigBlueButton.

Studies have shown that regardless of the delivery method, the usage of learning technologies can transform the concept of teaching and learning by redefining the role of the teacher and learner which is more of a constructivist approach fostered by web-based instruction where learning is a more authentic self-directed experience (Wakasa, 2021). That is, learning is a more self-directed experience that requires self-discipline.

At the heart of this study are the teaching strategies employed in the eLearning classroom and especially how they are thought of and implemented to promote meaning-making in the classroom.

The teaching methods involved in a fully online classroom include:

- Meetings and tutorials -This teaching strategy serves as a communication strategy where the lecturer and students can communicate (Ramos-Pla et al., 2022).
- Assessment – This teaching strategy takes place on Google Forms, Kahoot, EdPuzzle, Mentimeter, etc (Ramos-Pla et al., 2022).
- Presentations/dynamization tools- This teaching strategy takes place via PowerPoint, Canva, etc (Ramos-Pla et al., 2022).

In this regard, the lecturer provides facilities that encourage students to research to discover new knowledge through individualized initiatives and self-designed styles; individual or group tasks are guided by specific milestones (Wakasa, 2022). Students construct their knowledge and solve problems as they view topics from multiple perspectives; they become autonomous managers of their learning and devise questions for which they seek answers. This is fundamental in meaning-making, learning as meaning-making entails learning is acquiring knowledge, skills, or dispositions that enable the learner to act, think, and feel in ways that are recognized as important by oneself or others (Zittoun, 2012).

According to, Zittoun (2012) the study of meaning-making is defined as the process of how individuals make sense of knowledge, experience, and relationships. The concepts of cell

structure and function are perceived as difficult to learn by students (Cimer, 2011). The reason for this difficulty on the nature of the subject matter, and the teaching and learning process, thus leading to a poor comprehension of cell biology concepts which then leads to misconceptions (Zittoun,2012). Therefore, one can deduce that the study of meaning-making can be used to alleviate the problem of poor understanding of cell biology among students.

This study focuses on how the student makes sense of knowledge, and the student's ability to gain a comprehensive understanding of the content thereby mastering the articulation and construction of the content or topic being taught (Tang, Delgado & Moje, 2014). That means, by gaining a comprehensive understanding, the student will be able to own the knowledge by giving it their structure and communicate the knowledge in their way. Literature postulates that meaning-making can be promoted in eLearning classrooms by using teaching strategies that encourage engagement (i.e., the use of multiple representations and language) (Tang, Delgado & Moje, 2014). Therefore, the research aims to investigate the teaching strategies including how they presented language and representations to promote meaning-making in the teaching and learning of cell biology in an eLearning classroom.

Successful learning in the field of Natural sciences is closely related to the methods used by teachers and students (Mashau & Nyawo, 2021). Cell biology is currently mainly taught through lectures and laboratory classes, with the lecture being the main teaching process (Cimer,2011). Teaching through lecturing creates passive learning because the format of lecturing is teacher-centered, thus this, in turn, creates disengaged students (Zittoun, 2012). The danger of disengaged students is that they become passive and meaningful learning cannot take place (Zittoun, 2012). Therefore, this study seeks to investigate how teaching strategies can promote meaning-making in the teaching and learning of cell biology in an eLearning classroom.

1.1 Research problem/ problem statement

The study of meaning-making is central to education because it answers questions that are critical to learning. Lecturers should be well equipped with knowledge of how they can construct a lesson that will enable engagement in an e-learning classroom. Thus, this study aims to look at how teaching strategies should be implemented in an eLearning classroom to promote meaning-making when teaching cell biology.

The changing times and technological developments have offered universities an opportunity to change the vision of their educational programs offered to students. The innovative method of teaching and learning fostered by universities is eLearning. In the haze of the rise of this innovative teaching and learning method, many institutions face great impediments in providing effective teaching and learning practices (Mlitwa & Van Belle, 2011). According to Mlitwa and Van Belle (2011), several impediments hinder the innovation of online learning, these include socio-economic factors, infrastructure shortage, technology instability, technological cost, lecturer efforts, lack of online learning culture, students' vexation with online learning, inadequate ITC skills, and students' under-preparedness for higher education learning institutions.

Considering these challenges, lecturers are encouraged by higher education to utilize digital platforms for learning. Mlitwa and Van Belle (2011) postulate that lecturers are entrusted with the greatest task in education, to teach in eLearning classrooms which has great advantages but also great disadvantages. Literature has postulated that one of the impediments to online learning is the under-preparedness of lectures and the teaching strategies used in an eLearning classroom.

In light of the disadvantages posed by the eLearning classroom lies the impediment it has towards the meaning-making of cell biology. The under-preparedness of lectures for meaning-making may contribute to them continuing to use teaching strategies that hinder meaningful learning. DiCarlo (2006) postulates that lecturers still prefer the traditional way of teaching which promotes the process of transfer of knowledge to students through lectures and note-taking rather than advocating for student involvement in the learning process which disengages students thus promoting passive learning.

It becomes important to investigate teaching strategies as they are the ones critical in conveying concepts to students, teaching strategies employed in an eLearning classroom must promote engagement. Ignelzi (2000) argues that when students are disengaged, meaningful learning cannot occur. The study of meaningful learning aims to contribute knowledge to understand how human beings learn (Zittoun & Brinkmann, 2012). Therefore, the study of meaning-making provides us with insight on the basis that each learner must construct his/her understanding of concepts.

The study of meaning-making is paramount in the teaching and learning of cell biology. The reason for such a bold statement lies in the abstractedness of the course of cell biology which plays a pivotal role in a student's understanding of how cell structure is adapted to perform its function. The level of abstractedness of the course of cell biology prevents meaningful learning, DiCarlo (2006) argues that students find it easier to learn cell biology through memorization due to the abstractness of the course. Therefore, this creates passive learning which does not promote meaning-making.

The process of memorizing concepts is associated with failing to create schemas, which occurs when concepts do not align with prior knowledge (Carlan, Sepel & Loreto, 2014). Memorization is only fruitful for examinations however, it nullifies the concept of one being an independent thinker as it does not allow a student to integrate new knowledge into existing schemas thus the "new" knowledge cannot help the learner in solving new problems (Carlan, Sepel & Loreto, 2014).

Learning that is not meaningful poses a threat to science education because it encourages the mistaken belief that science is about learning the correct answer rather than comprehension, inquiry, and creativity, among others (Carlan, Sepel & Loreto, 2014). This inaccurate portrayal of science cultivates uninspired learners who are not challenged by science, therefore this detriments innovation and ultimately leads to a transfer to other disciplines or dropping out of school (DiCarlo, 2006).

Educators can encourage how learners make sense of knowledge by carefully structuring information in a way that enforces understanding and the use of a teaching strategy that

engages students in a way that matters to them concurrently encouraging meaning-making (Carlan, Sepel & Loreto, 2014). It is pivotal to emphasize the importance of content knowledge and concentrate on processes such as reasoning, analyzing, and the ability to think (Oztap, Ozay & Oztap, 2003). These processes encourage long-term learning and contribute greatly to the lives of student and their ability to contribute to society (DiCarlo, 2006).

1.2 Significance of the study

This study should serve as a reference to educators who wish to find out how teaching strategies intended to promote meaning-making in the teaching and learning of cell biology in an eLearning classroom. From the findings, teachers will be able to understand which teaching strategies are important for the design and implementation of their lessons in an eLearning classroom. It will also identify the appropriate teaching and learning strategies that influence learners and enkindle their interest to study and participate effectively in an eLearning classroom thus promoting meaning-making in teaching and learning of biology concepts.

It is also expected that the study will be of substantial significance to researchers who wish to embark on further research on how teaching strategies intended to promote meaning-making in the teaching and learning of cell biology in an eLearning classroom and fill the research gaps. Finally, the findings of this study will contribute to the benefit of an individual learner and society considering that life sciences play an important role in science today. The greater demand for graduates in bioinformatics, biochemistry, and genetics among others justifies the need for more effective teaching methods in promoting meaningful learning. Thus, lecturers who apply the recommended approach derived from this study will be able to train students better.

1.3 Objectives of the study

This research aims to understand how teaching strategies intended to promote meaning-making in the teaching and learning of cell biology in an eLearning classroom have been used. The study aims to address this question by specifically looking at which teaching strategies are used in an eLearning classroom and how they are used in the learning of cell biology in the eLearning classroom. The study aims to contribute knowledge in meaning-making and how it can be promoted with specific reference to cell biology. Moreover, the study also aims to contribute knowledge to our better understanding of how the different teaching and learning strategies may promote the learning of cell biology in eLearning classrooms.

<u>The objectives of this study are to:</u>

1.3.1 To investigate teaching strategies that the lecturer uses to promote meaning-making when teaching cell biology in an eLearning classroom.

1.3.2 To establish how the lecturer uses identified teaching strategies to promote the meaning-making of cell biology concepts in an eLearning classroom.

1.5 Research questions

1.5.1 Main research question:

What are the teaching strategies that are intended to promote meaning-making in the teaching and learning of cell biology and how are they used in an eLearning classroom?

1.5.2 Sub-research questions

The sub-questions that were posed in this research to guide this study are:

1.5.2.1 What teaching strategies does the lecturer use to promote meaning-making when teaching cell biology in an eLearning classroom?

1.5.2.2 How does the lecturer use the identified teaching strategies to promote the meaning-making of cell biology concepts?

1.6 Research instrument, time, and place of the study

The study seeks to investigate meaning-making which can be promoted with the use of various teaching strategies, thus it becomes central that a qualitative research design is employed here. Aspers & Corte (2019) argue that a qualitative research design is suitable for generating data for describing, interpreting, contextualizing, and gaining in-depth insight into specific concepts or phenomena. The study was conducted at a South African university. One lecturer was invited to participate in this study, the lecturer participated voluntarily based on anonymity and confidentiality.

The BigBluebutton video recordings of the lecturer teaching cell biology were watched then the lecturer was interviewed. The teaching of cell biology by the lecturer through the use of various teaching strategies was observed. A semi-structured interview was the instrument that was used to gain insight into how he structured the lesson, why he chose and how he used the various teaching strategies when teaching cell biology in an eLearning classroom.

1.7 Scope and limitations

The limitation of the study was that only three videos of 2 hours each (totaling 6 hours) were observed of one lecturer and only that one lecturer was interviewed, which entails that deduction can be drawn from one subject. A single topic was investigated because of the manner of this master's project so it was not possible to consider other biology concepts that are perceived as difficult to conceptualize by students such as meiosis, genetics, cellular respiration, and photosynthesis among others but were limited to only focus on cell biology. This then resulted in the study only reporting on the role of teaching strategies when teaching only one topic which is cell biology in an eLearning classroom.

1.8 Outline of the research proposal

- Chapter One introduced the study, in this chapter the key aspects of the study were defined. This chapter also highlighted the research and problem statement. This chapter answered why the study was going to be investigated, it also highlighted the objectives of the study as well as the research questions that were posed in the study.
- Chapter two outlined the literature that was reviewed in the study and the theoretical framework.

- Chapter three outlined the research design and methodology. This chapter highlighted the methodology that was going to be undertaken to answer the research questions posed by the study. This chapter also addressed the reliability and validity of the study and lastly how ethical issues are going to be addressed.
- Chapter four outlined the data analysis and presentation of findings.
- Chapter five outlined the discussion of findings and conclusion.

1.9 Conclusion

In summary, this chapter provided a brief outline of the study. It also summarised the following: the introduction statement, problem statement, significance of the study, objectives of the study, research methodology, time, and place of the study finally the scope and limitation of the study. The next chapter will unpack all the concepts introduced in this chapter.

CHAPTER TWO

Literature review and the theoretical framework

The previous chapter outlined and introduced the problem investigated in this study. This chapter examined existing literature within the broad area of how an individual learner constructs meaning when taught cell biology in an eLearning classroom. The chapter starts by defining the concept of meaning-making and then describes how this concept is promoted in teaching and learning by defining learning theories that guide this study. The subject matter of cell biology was then defined, moreover elucidated on what makes its teaching and learning difficult. Due to the COVID-19 pandemic, the traditional classroom has shifted into an eLearning classroom, thus this chapter defines what an eLearning classroom is the advantages and disadvantages of its implementation, and lastly how universities use eLearning. Moreover, upon completion, the chapter will describe the teaching strategies employed in eLearning and how they promote meaning-making. Furthermore, the chapter will describe and elucidate the theoretical framework that guides this study which is TPACK.

2.1 What is meaning-making?

The process of meaning-making is defined as an ongoing process whereby human beings construct understanding and interpret situations considering their prior knowledge and experience (Zittouni & Brinkmann, 2012). Meaning-making is a process of learning since it involves developing a new understanding of knowledge which Vygotsky (1978) defines as expanding the mind. It is ongoing because learning arising from meaning-making at any one time becomes prior knowledge for future learning opportunities. Therefore, meaning-making is a never-ending process by which humans make sense of the situations in which they find themselves. The implication is that when students are in a situation where they are provided with tools to interact with knowledge, they make sense of it.

That is human beings are meaning-making beings, and Ruetenik (2008) put forward that the role of meaning is of absolute significance in human life. “Meaning-making is also defined as a process of how an individual learner makes sense of knowledge” (Vallori, 2014). That means, meaning making happens at an individual level. Furthermore, meaning-making is supported by interactions and exploration of thoughts, actions, and knowledge (Vallori, 2014).

In a classroom context, this process is facilitated during lessons and involves the educator and learners. Therefore, there should be an interaction between a lecturer and a student where there is an exploration and sharing of ideas that promote meaning-making in the classroom. That the intrinsic nature of human beings is to understand and make meaning of their lives and experiences and draw meanings from or give meanings to, events and experiences (Zittouni & Brinkmann, 2012). That is difficult concepts to comprehend such as cell biology should be taught in such a way that students can draw on their own experiences, thus promoting engagement.

While meaning-making is an intrinsic process, it can be facilitated by an outsider, who, in the eLearning classroom setting, is the teacher. The teacher has to enable learners to interact with knowledge so that they can make meaning of it.

Meaning-making occurs in a particular setting or context (Nielsen, 2012). This entails that individuals interpret information that they receive from their environment, therefore learners in a classroom context are in an ongoing process of interpreting the information that they receive. That means the context in which the learner is immersed when they receive information influences the way that the learner interprets the information. In the context of the classroom, information received by learners tends to be used for developing an understanding of curriculum concepts (Zittouni & Brinkmann, 2012).

The implication is that a teacher has to facilitate meaning-making about the concepts that are being developed. This is what Sarioglan & Kucukozer, (2017) refer to when they say that meaning-making forms the main purpose of all conceptual change approaches. Further, the interpretation of the same information in different contexts is likely to result in different meanings that are related to those contexts.

Learning can be defined as a process of meaning-making. "Learning as meaning-making denotes that in any given situation of learning, human beings become actively engaged in making sense of the situation" (Zittouni & Brinkmann, 2012, p.2). This infers that when a learner is engaged in the classroom, they do not passively accumulate facts however they are trained to think thereby making meaning of what is being taught. Therefore, meaning-making in learning entails the creation and expansion of understanding and the ability to use knowledge in different contexts. The educator, therefore, needs to consciously enable learners to be actively engaged during the learning process so they can in turn actively construct and reconstruct knowledge through meaning-making. Meaning-making is an approach that restructures knowledge (Sarioglan & Kucukozer, 2017). In the meaning-making approach, information is not passively transferred from teacher to students, however, students have a responsibility to form their meanings in their minds by interacting with each other in a social environment and with their teacher. Furthermore, students have the right to control their ideas in the instruction process they are in. The role of the teacher in this student-centered learning approach is to guide by asking thought-provoking questions that promote engagement thus meaning-making.

The process of meaning-making is central to education because it informs us how learning takes place. According to the literature reviewed, the distinguishing characteristics of what constitutes the *"Hallmarks of meaning-making"* are:

I. "An ongoing process whereby human beings construct understanding and interpret situations considering their prior knowledge and experience.
II. The process of how an individual learner makes sense of knowledge.
III. Meaning-making occurs in a particular setting or context.
IV. Active engagement is pivotal in knowledge construction.
V. And lastly meaning-making is a process that restructures knowledge" (Vallori, 2014).

Meaning-making therefore is a collection of processes that include active construction of understanding, interpretation of situations, working with learners' prior knowledge and experience, as well as structuring and restructuring of knowledge. At the heart of all these is the role of the teacher who must consciously facilitate the learning interactions. Teachers can

mostly influence the learning in their classrooms through how they engage their students in learning interactions. Therefore, this study sought to investigate the teaching strategies that promote the meaning-making of cell biology in an eLearning classroom.

2.2 Learning as meaning-making

Learning as meaning-making is a statement used in this paper to describe the phenomena of promoting a deep understanding of cell biology concepts. "One cannot fully comprehend human beings without understanding how experience and action are formed by the mind, and we cannot understand the mind without taking cultural systems of meaning into account" (Zittouni & Brinkmann, 2012). It becomes central when we study how human beings make sense of difficult concepts like "cell biology" we look at the process of knowledge construction holistically, it is through this lens we can fully comprehend what constitutes meaning-making. Zittouni & Brinkmann (2012) propose the semantic level of meaning-making as a lens to examine how meaning-making occurs.

Zittouni & Brinkmann (2012) postulate that the semantic level is concerned with the meaning of spoken language, written language, images, gestures, signs, and symbols. That is, these are the representations that are used in teaching and learning to promote meaning-making. Fei (2007) argues that upon generating semiotic representations, learners must interpret scientific meanings and then translate the meanings into different forms, which is where meaning-making is theorized to happen. This implies that when a student can interpret semiotic representations used by the lecturer and apply them to different concepts, they have achieved conceptual understanding through the semiotic modes thereby promoting meaning-making.

"On a semantic level, learning as meaning-making involves being socialized into cultural discursive systems of meaning" (Nielsen & Gutiérrez, 2021). Therefore, meaning-making predominantly takes place in a social setting like a classroom thus it becomes central that the lecturer creates an environment that is conducive to learning. This can be achieved when students understand their role in the social plane as participants. Active participation involves dialogue where discourses like language, words, and speech are used to promote meaning-making because it is in a dialogue where concepts, subjectivities, perspectives, and judgments can be confronted (Powell & Kalina, 2009). Therefore, it can be argued that it is in a dialogue that information is conveyed, references are made clear, and most importantly thoughts are implied which promotes mental scaffolding. "This idea was further developed by Vygotsky (1986) in his reflection on the relationship between language and thinking: Meaning-making appears as the process by which socially given and shared words organize thinking and how thinking gives life to words" (Powell & Kalina, 2009, p.241).

Learning and meaning-making aimed to elucidate how meaning is constructed in cell biology. Semiotic representations such as (spoken language, written language, images, gestures, signs, and symbols) are used to represent different aspects of scientific understanding and offer opportunities for exploring concepts, conducting experiments, recording findings, and disseminating understandings (Danielsson, 2016). Therefore, the ability of a teacher to

integrate semiotics into their teaching strategies plays a fundamental role in how learning and meaning-making take place.

2.3 Meaning-making and Learning Theories

The purpose of learning theories in education is to give us an insight into how learning takes place (Olusegun, 2015). This means that learning theories give us insight into how learning takes place in the classroom. "Meaning-making has been described earlier in this paper as a concept that is pivotal in teaching and learning because it explains how an individual makes sense of knowledge" (Vallori, 2014). Therefore, one can deduce that meaning-making is strengthened in learning theories because of its nature to explain not only how an individual achieves knowledge construction but also looks into how knowledge construction occurs in a social setting (i.e., the classroom).

The constructivist paradigm provides us with an insight into how human beings learn (Krauss, 2005). That is, the constructivist paradigm explains how learning occurs. Powell & Kalina (2009) put forward that the teaching strategies used by constructivist teachers promote critical thinking in learners thereby promoting meaning-making. Critical thinking is achieved when a learner is engaged in the classroom (Powell & Kalina, 2009).

This paper has defined one of the hallmarks that promote meaning-making as active engagement therefore, it becomes imperative that teaching strategies that promote engagement are used in the classroom. It is observed that when one uses the teaching strategies postulated by constructivists students become active participants in the learning process (Nielsen, 2012).

The teaching strategies that promote active engagement and consequently critical thinking include providing students with problem-solving and authentic tasks which create a rich environment and experience for meaningful learning to take place (Nielsen, 2012). This is fundamental in meaning-making because learners should be actively engaged in the learning process for meaning-making to take place.

Cimer (2012) postulates that the role of a teacher in the constructivist classroom is to help students build their knowledge. Thus, the teacher in this paradigm is responsible for assisting in knowledge construction as well as helping students restructure knowledge thereby promoting conceptual change and consequently promoting meaning-making.

Moreover, the constructivist teacher values learner reflection and cognitive conflict and encourages peer interaction (Powell & Kalina, 2009). This is fundamental in meaning-making because it is in creating cognitive conflict when teaching topics that are difficult to conceptualize so that one can gauge what learners understand thus assisting learners to assimilate concepts and thus promoting understanding and the ability to interpret situations. To promote meaningful learning, one cannot separate understanding from it. Cimer (2012) postulates that the phenomenon of understanding is observed when a student can extrapolate what has been learned and apply it in different contexts.

Piaget focuses on individuals and how they construct knowledge (Powell and Kalina, 2009). This is essential in meaning-making because the process of meaning-making gives us insight into how individuals construct knowledge and meaning. In Piaget`s theory of cognitive constructivism, people cannot be given information they can immediately understand and use, but the sole responsibility for knowing and creating meaning rests with the learner (Driver et al., 1994). In other words, teachers need to understand that students cannot absorb the information they are given immediately. Therefore, meaning-making is an ongoing process and requires active students for them to build their knowledge.

Piaget postulated stages of logical development aimed at addressing the learning abilities of individuals of different ages (Powell and Kalina, 2009). His theory of equilibrium, assimilation, and adaptation is based on children's ability to construct knowledge and deal with conflict when presented with new information (Powell and Kalina, 2009). Cognitive constructivism is important in trying to understand meaning-making because it explains cognitive abilities at the individual level. This provides teachers with the lens they need to teach for meaning. This means that every student is different, and so will have a different way of understanding concepts.

It can be argued that the way cognitive theory studies individuals in knowledge construction is related to the discovery of meaning. Finally, they understand that the "one size fits all" formula does not simultaneously lead to conceptual change and does not contribute to long-term learning.

Knowledge construction at the individual level examines the prior knowledge of the learner. In cell biology teaching and learning, it is essential to examine the learner's existing knowledge to determine prior knowledge. Cimer (2007) argues that learning makes it essential for students to make a conscious effort to make clear connections between previous knowledge and new knowledge. This means that once teachers understand where each learner is cognitively (that is, at a particular point), they can teach learners to grasp concepts logically and intellectually, within their skill set. Thus, this means that learners can generate personal meaning when presented with new information.

The work of Vygotsky gave rise to a paradigm of learning called social constructivism. The work of Vygotsky has been established on the basis that learning occurs when there is classroom validation and social interaction and personal thought processes (Powell and Kalina, 2009). Fundamentally, social constructivism looks at students as meaningful beings. “Vygotsky focused on how meaning is constructed through social interaction and how the word meaning plays a role in the development of thought” (Mahn, 1999). Thus, people construct meaning in the social space in which their interactions take place.

According to Powel & Kalina (2009), a good support system can help learners solve problems, no matter how difficult the concept is. Collaborative learning is therefore an essential concept for a deeper understanding of concepts. Difficult concepts are easier to understand when learners are supported in a social environment. A good support system means collaboration.

The word meaning is argued to include both thought and speech (Mahn,1999). The use of written and spoken language presupposes thought and knowledge for the individual to construct meaning. Vygotsky's theory of development and all of its linguistic aspects are distinct concepts aimed at explaining how meaning is constructed at the individual and societal levels (Mahn, 1999).

The two paradigms considered above contribute significantly to effective teaching and learning in the classroom. “Both theories recognize the importance of the question and answer as a teaching strategy, this means that prior knowledge is important in both theories” (Powell and Kalina, 2009). Both theories recognize the importance of instruction in teaching and learning as the student builds knowledge and understanding of the concepts being taught (Driver et al., 1994). Students need support and guidance when being taught complex topics. Therefore, learning theories provide insight into how people learn. Fully complex learning involves negotiating meaning-making (Nielsen, 2012). “Meaningful learning is governed by three principles. People actively construct reality and meaning-making is an ongoing process that occurs over time, and finally, the process of teaching and learning is strongly influenced by the way participants create meaning” (Ignelzi, 2002). The teaching strategies educators choose have a profound impact on how learners understand cell biology.

2.4 What is cell biology?

Cell biology is a common theme in all areas of biology (Carlan et al., 2014). Cells have been defined as the basic structural and functional unit of all living organisms (Ellinger & Ellinger, 2014). Cells are defined as the structural units of organisms and defined as functional units because they form the building blocks that make up an organism (Ellinger & Ellinger, 2014).

“Cell biology is a subject matter that promotes the learning of the functioning of cells beyond their membranes, this phenomenon extends the appreciation of the complexity of how multicellular organisms function” (Carlan et al., 2014). Veselinovska et al., (2011) postulate that cell biology is an important basic subject of modern life sciences, consisting of fundamental life activities of the cell at the microscopic, sub-microscopic, and molecular levels. “Moreover, the fundamental concepts of cell biology allow us to relate and link cell biology concepts to mathematics, biophysics, and bioinformatics” (Carlan, Sepal & Loreto, 2014). “The knowledge of cell biology allows us to manage available information effectively thereby making better and more informed decisions in our daily lives” (DiCarlo, 2006).

2.5 Why is the teaching and learning of the cell considered difficult?

The basic concepts of cell biology are essential for scientific literacy and understanding, scientific investigations, and the appreciation of the history and importance of cell biology concepts in society. It is in understanding the elements that make cell biology a concept that is difficult to learn we can alternatively improve teaching strategies in online classrooms. The concept of meaning-making is an ongoing process that requires adaptable teaching strategies.

Literature denotes that, “one of the factors that hinder students from understanding cell biology is the abstractness and level of organization of the subject matter” (Cimer, 2012).

That is, the cell is abstract meaning it cannot be seen with the naked eye, it is microscopic. Therefore, it becomes difficult for students to make sense of the meaning of what they cannot visualize. It is argued that "another reason for students' difficulty in understanding cell biology is the overloaded terminology and content on the curriculum that is expected to be covered, as well as the time that the content is expected to be covered, which is not enough" (Carlan, Sepal & Loreto,2014). This implies that when there is an overload in content and terminology meaningful learning is prevented because cognitive overload is created, which leads to memorizing the terms for exams and tests thus preventing meaningful learning. This suggests that the limited time denoted to teach and learn cell biology may contribute to learners not receiving an opportunity to understand cell biology concepts. Thus, when learning does not involve understanding students "tend to memorize concepts with the sole purpose to pass, nullifying the need to acquire a deep understanding of the subject and developing lifelong skills such as critical thinking" (Carlan, Sepel & Loreto, 2014). That is, memorization is the acquisition of facts without association with prior knowledge.

"The existing researchers, for example, who have discussed what students know about the structure and functioning of cells suggest that most students find this topic difficult to conceptualize" (Tibell & Rundgren, 2010). That is, students, find the subject matter of cell biology difficult to understand. Tibell & Rundgren (2010) suggest that the reason for this difficulty is students failing to establish a relationship between cell structures and their functions as well as to integrate them into the overall picture of the cell. The two fundamental relationships that govern Life sciences which are structure and function as well as the surface area to volume ratio become impossible to grasp when one cannot visualize the subject matter thereby hindering meaningful learning.

The subject matter of cell biology has Latin terminology which is difficult to conceptualize (Cimer, 2012). The language of teaching and learning is English and not Latin; therefore, the Latin language forms a barrier to understanding cell biology thus preventing meaningful learning.

Based on the observation result of cell biology learning, most students assumed cell biology was a complicated subject (Prayitno, 2019). That is, the level of conceptual understanding regarding the subject matter is low. According to the test results of learners shown in Prayitno's paper, there was a misconception about cell structure as a solid and non-porous structure. This misconception was shown in students' drawings of the cell membrane. Therefore, it becomes central to understand that cell biology is a basic course and pre-requisite course for other classes in Biology Education; hence, concept mastery in the course is vital.

2.6 Meaning-making and the eLearning classroom.

The current pandemic of coronavirus spreads through the gathering of people and thus has led to dissociation even of groups in the classroom towards their individualized home study. Under this scenario, the traditional classroom context has fallen. Thus, the shift from the traditional classroom toward the digital age in which e-learning became desirable and compulsory. "Today's expeditiously environment and continuous changes in technology, the emergence of sophisticated teaching and learning tools and systems have the most remarkable positive developmental on the way students learn" (Mashau & Nyawo, 2021). Black (2019) stipulates that meaning-making often occurs during the action of managing and adapting teaching spaces and everything within those spaces. Therefore, this section reviewed the literature on eLearning; what is meant by eLearning, and the advantages and disadvantages of its adoption and implementation in teaching and learning. Furthermore, how it is used at the University of the Witwatersrand.

2.6.1 What is eLearning?

Electronic learning is often abbreviated to eLearning. It is defined as a learning program that makes use of an information network such as the Internet, an intranet (LAN), or an extranet (WAN) for course delivery, interaction, and/or facilitation (Ratheeswari, 2018). That is, students can access course-related materials via online computer systems because learning activities are supported by information and communication technologies (ICTs).

ICTs refer to technologies that provide access to information through telecommunication, that is they focus primarily on communication technologies (Kuldasheva, 2020). These communication technologies include the Internet, wireless networks, cell phones, and other communication mediums. As a learning program ICT is used in an eLearning classroom to advance student-oriented, active, open, collaborative, and life-long teaching and learning processes (Kuldasheva, 2020).

One of the characteristics of eLearning is that it includes all aspects of electronic delivery, therefore, to facilitate engagement which will promote meaning-making a lecturer can use educational videos, a digital camera, computer to edit pictures, text, or sounds for a presentation or project, or use an interactive whiteboard in a lesson to implement the eLearning classroom.

In this research, eLearning is defined as the use of the internet to access learning materials; interact with the content, instructor, and other students; and obtain support during the learning process, to acquire knowledge, construct personal meaning, and grow from the learning experience outside the traditional classroom. It becomes central to assimilate that the eLearning classroom defined in this research takes place predominantly outside the classroom.

The literature outlines characteristics that make a classroom an eLearning classroom as follows:

- The classroom must incorporate a multimedia environment (Arkorful & Abaidoo, 2014).
- The classroom must support collaborative communication and the users should have total control over their learning (Arkorful & Abaidoo, 2014).
- The classroom must support networks for accessing information (Arkorful & Abaidoo, 2014).
- The classroom should allow systems to be implemented freely on various kinds of computer operating systems (Arkorful & Abaidoo, 2014).

2.6.2 What are the advantages of the implementation of eLearning?

- ***The eLearning classroom provides students with flexibility concerning their learning. This takes into consideration time, pace, and the learning space***. This means that every student has the luxury of choosing the time they choose to engage with the content, the pace that suits their learning, and lastly, the space in which they learn. Flexibility in teaching and learning that is provided by the eLearning classroom promotes the ability to retain greater knowledge as individual students interact with the content at their comfort which then promotes high interactivity with the lecturer and content being taught promoting meaning-making. Heightened student interaction with the concepts being taught increases the ability to concentrate. This then promotes engagement which in turn promotes meaning-making.
- ***The eLearning classroom provides self-education opportunities***, this prospect is honed when students can work on their own time. Self-learning enhances the constructiveness of knowledge which promotes meaning-making. Learning in this regard is designed to suit the preferred learning styles of an individual student.
- ***eLearning enhances the efficacy of knowledge***. This is achieved by broadening the opportunities to present the course content in a way that better suits the needs of the learners, that is learning is personalized which promotes engagement thus promoting meaning-making.
- ***The eLearning classroom allows multiple teaching strategies to be used***. The eLearning classroom uses interactive teaching strategies that promote engagement and meaning-making. One of the strategies is an interactive video platform that allows students to watch all activities that are conducted in the classroom and also listen to instructors as many times as needed. The act of being able to listen to the lecturer multiple times promotes a deeper meaning of concepts such that it eradicates misconceptions by facilitating understanding of what is being taught. This teaching strategy offers teachers with several ways of interacting with learners and to give them instantaneous feedback.
- ***The eLearning classroom promotes instant feedback***. Instantaneous feedback in education facilitates understanding. Instant feedback helps an individual student deepen their understanding, this is achieved by reinforcing knowledge through

correcting mistakes, affirming competence, or debunking misconceptions on the topic. When students understand the concepts they are being taught, they can make schemas using their prior knowledge. Therefore, an individual student can make necessary connections that will help deepen their understanding thus facilitating meaningful learning.

- ***eLearning promotes student participation***. The eLearning classroom can provide opportunities for relations between students through the use of discussion forums. Through this, eLearning helps eliminate barriers that have the potential of hindering participation including the fear of talking to other students. One of the hallmarks of meaning-making is engagement, when students are engaged during the learning process, they show active involvement that is they participate. Meaning-making in this regard is promoted by active involvement whereby students interact with each other, as well as exchange and respect different points of view, this improves the relationships that sustain learning. Wagner et al (2008) postulate that the eLearning classroom also makes available extra prospects for interactivity between students and teachers during content delivery.
- ***eLearning always takes into consideration the individual learners' learning styles***. The eLearning classroom is diverse in course delivery, for instance, it caters to visual, social, auditory, and kinaesthetic students. Therefore, in an eLearning classroom, every student is engaged during each stage of teaching and learning, which promotes participation. Thus, students can create a deeper meaning of concepts that are taught in class.
- ***Students indicate a higher interest in learning strategies related to computers*** (Jang & Tsai, 2013). This implies that when teaching and learning occur in an eLearning classroom, the interest of learners is heightened which facilitates active learning. Active learning is a phenomenon that shows engagement when students ask questions and contribute to their learning process engagement is promoted. Therefore when students are engaged during the teaching and learning process it promotes a deeper understanding and questioning of concepts that are taught which promotes meaning-making.

In summary, the above-mentioned advantages denote that the eLearning classroom is a learning platform that is capable of influencing how students construct and make meaning by noting the ability of an eLearning classroom to assess the students as they learn, and at the same time increasing their experiences in education by catering to diverse learning styles, promoting participation, and eradicating boundaries of place and time. One could postulate that the most vital characteristic as well as advantage of eLearning in education is that it is student-centred which then promotes active learning whereby students actively question concepts they are being taught and contribute to the learning process. Active engagement that is promoted by the eLearning classroom allows objectives to be accomplished in the shortest time with the least amount of effort. This is achieved because an eLearning classroom creates an environment that aids students to depend on themselves since lectures are no longer the solitary source of knowledge. They instead become advisors and guiders (Alsalem, 2004). This then creates students who actively pursue knowledge and question concepts in the social

plane then individualizes the concepts by making sense of the new knowledge being taught which promotes meaningful learning.

2.6.3 What are the disadvantages of the implementation of eLearning?

Despite the advantages of eLearning in education, it has some disadvantages. The disadvantages stated by the literature include the following:

- ***eLearning as a method of education makes the learners undergo contemplation, remoteness, as well as lack of interaction or relation***. It becomes paramount to note that meaningful learning involves the negotiation of concepts in the social plane. Concepts such as cell biology that are difficult to comprehend require collaboration, whereby individual students support each other to better understand what is being taught. That is, students are recognized as participants in teaching and learning thus when students are unable to interact with each other due to remoteness ideas cannot be shared among students which hinders the process of meaning-making in an eLearning classroom.
- ***The eLearning classroom is less effective concerning clarifications, explanations, as well as interpretations of concepts, this is based on the absence of face-to-face interactions***. Thus, this entails that students are unable to assimilate and create a deeper understanding of concepts taught in an eLearning classroom, abstract and difficult concepts such as cell biology thus hindering the promotion of meaning-making. Almosa (2002) postulates that the learning process is much easier with the use of face-to-face encounters with lectures.
- ***eLearning increases the likelihood of plagiarism*.** Plagiarism causes students not to be able to read academic papers with understanding and being able to select work that is relevant to the assignment at hand. Thus, this hinders meaningful learning.
- ***When it comes to improvement in the communication skills of students, eLearning as a method has a negative effect***. Being able to articulate ideas is paramount in meaningful learning because ideas are shared on the social plane before they are internalized by individual students. That is, though a student might have excellent knowledge of cell biology, they may not possess the needed skills to deliver their acquired knowledge to others. Mahn (1999) argues that meaning incorporates thought and speech, therefore spoken language presupposes thought and knowledge for the individual to construct meaning.
- ***Cell biology practical's cannot be employed in an eLearning classroom***. This entails that practical skills cannot be taught therefore making it impossible to eliminate the abstractness of the course of cell biology. That is, the use of practical's makes it possible for students to visualize the cell under the microscope to better understand its size and complexity.
- ***Barack (2007) postulates that students lack the necessary knowledge and skills about utilizing technology which can limit the effectiveness of integrating technology into their learning***. South Africa is a developing country that has a high rate of unemployment, poverty, and socioeconomic inequalities (StatsSA, 2019). Socioeconomic inequalities have had a negative contribution to the ability of students to use and access technology and gain ICT skills. Numerous first-year university

students, most predominantly the ones who matriculated from rural areas without access to modern technology struggle when they have to use computers as they lack basic ICT skills. The inability to utilize technology hinders students from engaging and participating optimally in an eLearning classroom which could potentially limit how they understand concepts thus leading to the development of misconceptions and memorization. Meaningful learning requires the ability to be able to understand and interpret concepts.

2.6.4 eLearning platforms used by the University of Witwatersrand, and how are they used?

The automated way of learning and interacting with students has a lot of advantages that can be accomplished through different systems. Among them, the most popular approach is the use of a learning management system "Canvas". Canvas is a platform that connects lecturers and students in an eLearning classroom. The University of the Witwatersrand uses a canvas called ulwazi. Ulwazi is the Wits Learning Management System (LMS) that uses the Canvas online platform to support teaching and learning. The tools that are integrated into the canvas enhance the teaching and learning experience.

2.6.4.1 Components integrated into Ulwazi that promote eLearning and meaning-making:

- Announcements: Students are updated on course information instantly.
- Assignments: Canvas Assignments use due date settings to trigger reminders to students, so they are less likely to miss assignments.
- Discussions: Canvas provides an integrated system for class discussions, allowing both instructors and students to start and contribute to as many discussion topics as desired. Discussions can be graded (and seamlessly integrated with the Canvas Gradebook), or ungraded (such as a forum about current events)
- Grading Control: Informs students of their performance in the course. Canvas maintains assignment integrity by enabling uploaded submissions, time-stamped entries, auto-graded assignments, instant feedback, annotations, and automatically weighted assignments among others.
- Inbox (Messages & Conversations): The Canvas Inbox functions like an email account that helps the lecturer communicate with students in all courses.
- Calendar: The global navigation menu displays a Calendar feature populating all class assignments to help the lecturer stay current and prevent missing out on completing an assignment for students or grading one for instructors.
- Conferencing "Blue button": Conferences make it easy to conduct synchronous (real-time) lectures for all the students in your course, allowing lecturers to broadcast real-time audio, video, and demo applications on your desktop, share presentation slides, or demo online resources.
- Chat: The Chat tool gives lecturers another option to keep virtual office hours and hold live conversations with students to answer their questions.
- Assignment Feedback: Instructors can easily give feedback on assignments, so students know what is expected.

2.7 Teaching strategies that facilitate meaning-making in an eLearning classroom.

The purpose of reviewing the literature on teaching strategies is to gauge how cell biology is taught in an eLearning classroom. Creating a lively learning environment in the classroom

increases student involvement in the educational process (Vallori, 2014). That is, when student involvement is increased in the teaching and learning process, student academic performance concurrently improves. This implies that meaning-making is dependent on student involvement.

Moreover, according to Vallori (2014), student involvement in the learning process assists students to recognize and accept their responsibility for lifelong learning and continued professional development. Thus, this section aims to explore teaching strategies and learning practices that have led to successful online participation and engagement in the teaching and learning of cell biology thereby promoting meaning-making.

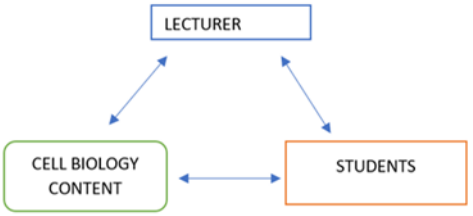
Sharoff (2019) argues that facilitating an online course in today's student population requires an educator to be innovative and creative and to have an impactful online presence. That is, facilitating an engaging online course requires educators to develop teaching strategies that encourage student engagement and build a sense of community. "In scientific teaching that emphasizes inquiry and research, interactions with instructors and peers are particularly valuable in helping students to construct meaning from their ideas and observations" (Yu et al., 2022). The negotiation of meaning using various teaching strategies between the lecturer and students promotes meaning-making.

It becomes central to explore the phenomenon of engagement when introducing teaching strategies. The definition of engagement has been extensively explored in the distance and online learning literature for decades. Student engagement is defined as "the student's psychological investment in an effort directed toward learning, understanding, or mastering the knowledge, skills, or crafts that academic work is intended to promote" (Martin, 2018, p.2). That is, student engagement entails being cognitively invested in the teaching and learning process. Moreover, it is when a student is invested in the teaching process that they can acquire knowledge thereby facilitating meaning-making.

The notion of "student engagement in online learning is very important because online students seem to have fewer opportunities to be engaged with the institution" (Martin & Bolliger, 2018). Hence, it is essential to create multiple opportunities that promote student engagement in the online classroom. Vallori (2014) denotes interactions and participation as the two fundamental principles that govern engagement in an eLearning classroom.

"Interactions with content, peers, and teachers help online learners become active and more engaged in their courses" (Martin & Bolliger, 2018). That is, it is through these interactions that are facilitated by discussions that engagement can be promoted in an eLearning classroom. According to Martin (2018), engagement in an eLearning classroom can be promoted by three basic interactions, namely: Lecturer-student interaction, Lecturer-content interaction, and lastly student-student interaction. Therefore, interactivity results in high-quality instruction, and more effective learning outcomes (Martin, 2018).

Figure I shows interactions that promote engagement in an eLearning classroom:



The following teaching strategies encourage [Lecturer-student interaction, Lecturer-content interaction, and lastly student-student interaction] in an eLearning classroom:

- **Collaborative learning teaching strategy:** entails learning that involves two or more learners, whereby knowledge is shared on a social plane. This teaching strategy involves group work, students facilitating presentations and discussions, sharing resources actively, creating course assignments with hands-on components, and integrating case studies and reflections (Martin, 2018). Sharoff (2019) argues that teaching strategies that promote engagement include collaborative learning. That is, it is by incorporating proactive and collaborative pedagogical practices such as group work and discussions, that students' engagement, motivation, commitment, and knowledge acquisition are encouraged and supported thus nurturing the learning process. Yu et al., (2022) postulate a "student's perception of a collaborative learning environment and development of self-efficacy and self-determination includes engaging in one-on-one discussions with the lecturer and just-in-time teaching". That is, when a lecturer offers guidance to students and encourages questioning which results in dialogue, students become actively engaged in the learning process thereby promoting intrinsic motivation which will in turn cause students to take control of their learning.
- **Discussion teaching strategy:** entails teaching by enabling students to share ideas through class discussions which promotes learner engagement. That is when students engage in discussions, peer-to-peer collaboration is encouraged and an engaging virtual learning dynamic is promoted (Martin & Bolliger, 2018). Moreover, this entails that it is when students are collaborating that a sense of community is promoted in an e-classroom thus inhibiting the sense of isolation and being alone (Martin & Bolliger ,2018).
- **Teaching by video conferencing:** Yu et al., (2022) suggest that the use of video conferencing in the teaching and learning of cell biology in an eLearning classroom has restored the necessary interpersonal interactions for student learning. That is, lecturers can interact optimally with students using video conferencing thereby facilitating explanations that concurrently promote meaning-making. "Moreover, the interaction between the lecturer and students can be supported by integrating digital social platforms, synchronous teaching, and active learning activities" (Yu et al., 2022). Thus, it is integrating these features in an eLearning classroom that promotes engagement thereby promoting meaning-making.

- **Inquiry-based learning teaching strategy:** entails a dialogue created when a lecturer asks students questions about the subject matter and they respond. This creates active learning through participation. Meaning-making is an ongoing process that requires student involvement and active participation in the learning environment. Moreover, according to Yu et al., (2022) inquiry-based learning promotes participation which in turn promotes engagement. Therefore, according to Yu et al., (2022), "lecturers should provide verbal or written support to students as they navigate creative scientific processes". That is, offering students feedback swiftly gives students the necessary guidance thereby contributing to the understanding of cell biology concepts better in an online classroom. Nevio (2002) argues that feedback is one of the most valuable tools in eLearning classrooms because educators can monitor and improve the performance of students in several ways.
- **Tutorials teaching strategy:** According to Yu et al. (2022), "peer interactions are valuable as students grapple with forming hypotheses, designing experiments, and interpreting data". That is, the interactions that occur between students in an eLearning classroom are of significance in meaning-making. One teaching strategy that promotes lecturer-student and student-student interaction is tutorials. According to Gleeson, McDonald & Williams (2017), one of the ideas behind these tutorials is to encourage students to teach each other, unravel problems themselves, and explain the issues to their peers. That is, tutorials result in a deeper understanding of concepts because students take the responsibility of solving problems on their own with the guidance of their tutor (i.e., their lecturer).

  Moreover, students develop communication and interpersonal skills. According to Gleeson, McDonald & Williams, (2017), a collaborative learning tutorial is a more intense and meaningful experience for students – one that enhances motivation and interest in their studies. That is, during a tutorial, students actively interact with each other and the lecturer, in contrast to their more passive role in lectures.
  Moreover, during a tutorial the student's questions are answered which provides clarification of cell biology concepts (Gleeson, McDonald & Williams, 2017). Therefore, the dialogue that occurs during tutorials addresses the misconceptions that students may have thereby correcting them. It is observed that students are exposed to different styles of thinking, and different ways of tackling problems (Yu et al., 2022). That is, in a classroom learner diversity exists and this also informs cognitive abilities. Therefore, different learners will share their views of cell biology concepts thus promoting deeper understanding.

  Tutorials offer interactions between students in small groups which promotes communication and interpersonal skills. In these groups, students ask each other questions and advice, sometimes accepting and at other times rejecting ideas, and then forming their own opinions by synthesizing the contributions of others with their own experience and knowledge. That is, it becomes central that students are directly involved in academic discourse and tutorials offer that direct involvement.

- **Teaching by powerpoint presentations, animations, analogies and visual aids**: Martin (2018) argues that student engagement increases the willingness of students to learn. Teaching methods such as narrated PowerPoint presentations, animated videos, analogies, and visual aids can be used to help students develop an understanding of new information, visualize new and abstract information and lastly motivate students to learn meaningfully (Ogrill, Bussey & Bodner, 2015).

That is, various teaching strategies can be used by the lecturer to achieve active learning thereby promoting engagement and meaning-making. It is when students are engaged in the learning process, that they become motivated to learn which will then improve their performance in eLearning courses.

Thus, Banna et al., (2015) postulate that engagement is the key solution to the issue of learner isolation, dropout, retention, and graduation rate in online learning. That is student engagement can be shown as evidence of students' considerable effort required for their cognitive development (Meyer, 2014). Moreover, when students are engaged in the learning process, they can construct understanding and bring about conceptual change by creating their knowledge thus leading to a high level of student success.

In summary, the lecturer is responsible for designing an online classroom that is engaging to students. Engagement in an online classroom includes student-centered learning activities and assessment tasks that will guide the students in their asynchronous learning.

2.8 Theoretical Framework

This study has utilized Mishra and Koehler's TPACK framework. The foundation of this framework is the apprehension that teaching and learning is an extremely multifaceted activity that draws on numerous kinds of knowledge, such as content, pedagogical, and technological knowledge, amongst others (Mishra and Koehler 2006).

Veselinovska et al., (2011) describe teaching as more than the presentation of information in an adequate manner. It is a process of incorporating the developmental readiness of a learner and assisting learners in constructing a developmental bridge between their current way of understanding and the new way of understanding (Ignelzi, 2002). For a teacher to do that successfully, they should be equipped with a knowledge base for teaching (Mavhunga, 2019). In other words, teaching is a codified aggregation of knowledge, skill, understanding, and technology of ethics and disposition of collective responsibility as well as a means of representing and communicating it (Mavhunga, 2019).

The purpose of reviewing the literature on the knowledge base for teaching and learning is that pedagogical content knowledge informs the teacher's content knowledge, procedural knowledge which is embedded in their instructional strategy and methodology, their knowledge of student's conceptions and preconceptions as well as learning difficulties (Kunene et al.,2018).

Koehler et al., (2014) define the knowledge base for teaching using technology; Technological Pedagogical, and Content Knowledge (TPACK) as the knowledge about the complex relations among technology, pedagogy, and content that enables teachers to develop

appropriate and context-specific teaching strategies. That is, TPACK is the kind of knowledge needed by teachers for effective technology integration in teaching and learning.

Mishra & Koehler (2006) postulate TPACK as a framework that is concerned with the basis of effective teaching with technology, requiring an understanding of the representation of concepts using technology, pedagogical techniques that use technologies in constructive ways to teach content, knowledge of what makes concepts easy or difficult to learn. That is technology can help redress some of the problems that students face regarding the content being taught, inform the teacher about students' prior knowledge and theories of epistemology, moreover, build on existing knowledge thereby helping to build new epistemologies and strengthen old ones.

Therefore, teachers' knowledge of integrating content, pedagogy, and technology has become important (Koehler et al., 2014). That is, the increasing availability of digital and networked tools has the potential to fundamentally transform the teaching and learning process.

The TPACK framework is as follows: This framework gives one a lens to understand the lesson plan formulated by the lecturer.

- content knowledge (CK) which describes the subject-matter knowledge that a teacher is responsible for teaching. Content knowledge in the present study describes the cell biology content that the lecturer intends to teach. In this section, we look at the outline of the course, and the sequence of the topics under cell biology.
- Pedagogical knowledge (PK) describes teacher knowledge about a variety of instructional practices, strategies, and methods to promote students' learning. In this section, we look at the instructional practices and strategies employed by the lecturer to facilitate meaning-making.
- Technology knowledge (TK) refers to teacher knowledge about traditional and new technologies that can be integrated into the curriculum. In this section, we look at how technology has been integrated into the teaching strategies that were chosen and how the integration facilitates meaning-making.

The TPACK framework suggests that teachers need to have a deep understanding of each of the above components of knowledge to orchestrate and coordinate technology, pedagogy, and content in teaching (Mishra & Koehler, 2006). Most importantly, TPACK is an emergent form of knowledge that goes beyond knowledge of content, pedagogy, and technology that has been taken individually but rather exists in a dynamic transactional relationship between the three components (Koehler & Mishra, 2008).

2.9 Conclusion

In this chapter, learning and meaning-making were explored in their full complexity. The chapter started by defining the concept of meaning-making and then described how this concept is promoted in teaching and learning by defining the learning theories that anchor meaning-making. The subject matter of cell biology was then defined and elucidated on what makes its teaching and learning difficult. Due to the current pandemic, the traditional

classroom has shifted into an eLearning classroom, thus this chapter defines what the eLearning classroom is and the advantages and disadvantages of its implementation, and lastly how Wits University uses eLearning. Moreover, the teaching strategies that promote engagement and participation in an eLearning classroom were elucidated. Furthermore, the chapter described the theoretical framework "TPACK" which guides this study.

CHAPTER THREE
RESEARCH DESIGN AND METHODOLOGY

Introduction

This research sought to establish how teaching strategies promote the meaning-making of cell biology concepts in an eLearning classroom. The purpose of this chapter is to elucidate the research design by describing the research approach, participants, research instruments, and how data is analyzed. Furthermore, the validity and reliability of the study and ways in which ethical considerations were addressed.

The research questions that guided this study were:

1. What teaching strategies does the lecturer use to promote meaning-making when teaching cell biology in an eLearning classroom?
2. How does the lecturer use the identified teaching strategies to promote the meaning-making of cell biology concepts?

3.1 Research design

A qualitative research design was employed in this study because it is concerned with the subject of meaning, which can be constructed by the interaction between the lecturer and students using creative and diverse teaching strategies. A qualitative research design is appropriate for generating data for describing, interpreting, contextualizing, and gaining in-depth insight into specific concepts or phenomena (Goundar, 2019).

Qualitative research is concerned with research about people's lives, lived experiences, behaviors, emotions, and feelings as well as about organizational functioning, social movements, cultural phenomena, and interactions between nations (Pandey & Pandey, 2015). Therefore, it becomes central that a qualitative research design is used in the subject of meaning-making that is concerned with how an individual learner constructs an understanding of cell biology concepts in an eLearning classroom.

Qualitative studies deal with understanding phenomena that naturally occur in specific contexts, where researchers do not manipulate the phenomena that they are interested in (Kielmann, Cataldo & Seeley, 2012). Concurrently, meaning-making is a phenomenon that occurs in a particular context/setting. A qualitative researcher focuses on capturing what people say and do, how they interpret the world, and how they feel about events in their lives (Goundar, 2019). This study is concerned with how the lecturer promotes meaning-making when teaching cell biology in an eLearning classroom, therefore it becomes central that one examines the teaching strategies employed by the lecturer and how they are used.

According to Goundar (2019), to capture and analyse unstructured information, qualitative researchers use interview transcripts and recordings, notes, feedback forms, photos and videos, verbal summaries of research findings, flow diagrams, and narrative descriptions of events and processes. That is, data collection in this research design involves collecting data that gives an insight into people's lives thereby obtaining an in-depth understanding of the process.

Goundar (2019) explains how the process of data collection takes place, the author starts by narrating that data collection commences with general research questions, collecting extensive verbal data from a few participants, coherently organizing data, and using verbal

descriptions to portray the situations they have studied. That is the aim of textual data context. The researcher plays an active role in interacting with the participants and becomes personally absorbed in the entire research process thus the researcher is the human instrument of data collection (Kielmann, Cataldo & Seeley, 2012).

3.2 Research approach

The research problem, the research aims, and the research questions in this study all suggested that a qualitative approach should be used to investigate the teaching strategies that are intended to promote meaning-making in the teaching and learning of cell biology and how are they used in an eLearning classroom. Since the study required an in-depth understanding of how meaning-making is promoted, the lecturer was observed when teaching, as well as the process was observed, and an interview was conducted with the lectures to gain in-depth insight which is best captured by employing a qualitative research design and methodology. A qualitative methodology uses an interpretative approach; and as such, it will unpack issues of meaning, observation, and understanding from the perspective of the key player themselves (namely, the lecturer and students).

The qualitative paradigm is based on interpretivism and constructivism (Goundar, 2019). Interpretivism is concerned with an understanding of complex human behavior and social settings (Pham, 2018). Interpretivism believes that most of our knowledge is gained through social constructions such as language, consciousness, shared meanings, documents, and other artifacts that have meaning in people's lives (Ryan, 2018).

Interpretivism was adopted as the epistemological perspective that is most suitable for this study. Epistemology focuses on how we acquire knowledge about a phenomenon that stems from a researcher's view of the world, in an interpretive paradigm, epistemology is subjective, as the researcher and the participants are engaged in jointly creating understandings (Kivunja & Kuyini, 2017). That is, it becomes imperative that social scientists understand and interpret the social world from individual participants' perspectives and recognize that their backgrounds will influence interpretations of the phenomenon under study. This study is concerned with how meaning-making is promoted thus we must gain insight into the reasoning behind the teaching strategies used and how the lecturer attempts to promote meaning in the classroom. Goundar (2019) argues that an interpretive epistemology allows for rich, in-depth data to be collected through in-depth explanations.

3.3 A case study method

The research approach chosen by this study sees a case study method appropriate for data collection. A case study can be defined as an empirical research technique used to investigate a contemporary phenomenon, focusing on the dynamics of a real-life context (Goundar, 2019). In a case study, one studies an individual, group, or phenomenon (Yin, 2003). This is done to gain a rich and in-depth explanation of the phenomenon being studied.

In a case study, a comprehensive description of an individual case and analysis is made as well as the characterization of the case and the events as well as the description of the discovery process of these features (Yin, 2002). The case and unit of analysis are how meaning-making can be promoted by a lecturer in the teaching of cell biology to 1st-year Natural science preservice teachers in an eLearning classroom. The case in this study is the *lecturer* who can also be denoted as the "unit of analysis". A case study is used in this study because it allowed the researcher to study an individual "lecturer" and a process (of teaching)

simultaneously, thereby allowing the case which is how the lecturer taught and for the lecturer to answer for themselves the "how" and "why" they chose certain teaching strategies (Goundar, 2019). A hallmark of case study research is the use of multiple data sources which includes interviews, observations, and content analysis in this study (Yin, Merriam & Stake, 2015). This fundamental characteristic allows the researcher to use multiple lenses in understanding how meaning-making is promoted.

A case study was used in this study because it permits the triangulation of data (Fabregues & Fetters, 2019), which allows the observer to collect data using different techniques including a video-stimulated interview, content analysis of presentations of the lectures, and the researcher's observation during the lecture. These ultimately gave the researcher insight into understanding how meaning-making can be promoted in the teaching and learning of cell biology in an eLearning classroom.

3.4 Population

The research participant was the lecturer whose teaching practice was analyzed. Even though 1st-year Natural Science students were part of the teaching transaction, they were not part of the study; hence, their participation was not analyzed.

3.5 Sample size and sampling procedure

This study used purposive sampling to gain information-rich cases such as the individual lecturer to gain in-depth information. Purposive sampling was used for document analysis of the narrated PowerPoint presentations. The Life sciences lecturer was chosen to participate in this study because they possess cell biology knowledge. Further, the lecturer is appropriate for the study because they are experienced in teaching cell biology at the university level and can provide the information the study requires to effectively answer the research questions. Only one lecturer was chosen to participate in this study because they are the only one who teaches the whole course of NSI cell biology and would be informed about how meaning-making can be promoted throughout cell biology.

3.6 Data collection

3.6.1 Data collection techniques

a. Video recording data

Video recording provides a sequence of moving images that may be replayed, for immediate or later viewing using a camera, recording device, and monitor screen (Edwards, 2004). Video recording allows the researcher to replay the pictures and sounds of an event (Edwards, 2004). As such, it is a valuable research tool. The use of video in research activity enables spontaneous and transitory information to be captured (Edwards, 2004).

Data in this research project was collected from watching video recordings of the lecturer which were taken when the lecturer was teaching the topic of cell biology to 1st-year Natural Sciences pre-service teachers. The advantages of video data are its ability to capture the interaction of the participant with the environment, capture nonverbal cues, and establish a permanent record (Lopez & Whitehead, 2013). A video recording of a lecture makes the lecture available beyond the lecturer's teaching time.

Video data is a durable, malleable, shareable record that can be repeatedly viewed and manipulated to be viewed in slow or fast motion, freeze-frame, with or without sound or image (Ramey et al, 2016). The use of video data enabled me as the researcher to revisit the data over some time, revisiting the video helped me develop an improved understanding of the data (Ramey et al., 2016). It has also been suggested that slowing down and speeding up the video can help researchers gain analytical distance and reflexivity by denaturalizing it (Radisic & Baucal, 2016).

A key advantage of using videos to collect data is that they support an exploratory research design or data-discovery phase (Radisic & Baucal, 2016). A video can be 're-opened' for more analytical passes than some other forms of data collection, notably, it can capture things that a researcher might not have noticed when conducting observations (Radisic & Baucal, 2016).

b. Video stimulated recall (VSR) interview

The video-stimulated recall is an action research method that is used in education (Rowe, 2009). The method includes recording a video of an activity and then replaying the recording to the participants so that they can comment on matters of interest (Rowe, 2009). These matters may be chosen by the researcher or by the participant (Rowe, 2009).

A video-stimulated interview was conducted with the lecturer. The interview was audiotaped. All the questions that were posed to the lecturer were generated after the researcher watched the video (See Appendix FIVE for the VSR interview transcript). This allowed the lecturer to provide and recall reasons for the decisions they had made while teaching. The key elements of the video-stimulated interview included sections related to the beginning of the lesson, introduction of new concepts, and facilitating discussion and/ or problem-solving process. The interview lasted for five minutes, it was expected to last for 10 minutes. The point in which the interview was done was when the lecturer reflected on their behavior and their decision-making processes during the lesson.

c. Document analysis

Document analysis is a systematic procedure for reviewing or evaluating both printed and electronic documents (Bowen, 2009). Document analysis requires data to be examined and interpreted to elicit meaning, gain understanding, and develop empirical knowledge. Documents such as PowerPoint presentations are teaching resources that contain text and images and can be analyzed because they have been designed without the researcher's intervention. Furthermore, the PowerPoint presentations provided supplementary research data and valuable additions to a knowledge base. The document analysis is used in this study as a means of triangulation of data to gain in-depth meaning of how meaning-making is promoted when teaching cell biology to first-year Natural science preservice teachers. As part of data collection, PowerPoint presentations were analyzed by reading through them thoroughly which provided a thorough examination and interpretation.

3.7 Data analysis

Qualitative data analysis includes taking the collected data and transforming it into a form of explanation, understanding, or interpretation of the people or situations being investigated (Skinner *et al*., 2015). Qualitative data in this study is in the form of words that are derived from observations, interview recordings, and document analysis this data has to be summarized, organized, described, and interpreted. Data analysis for this study was inductive.

This data analysis approach was associated with the qualitative aspect of the research and was guided by the research questions and the theoretical framework.

A thematic analysis was used to analyze the data. Thematic analysis is a form of pattern recognition within the data, with emerging themes becoming the categories for analysis (Bowen, 2009). The process involves a careful, more focused rereading and review of the data (Thomas, 2003). The reviewer takes a closer look at the selected data and performs coding and category construction, based on the data characteristics, to uncover themes pertinent to a phenomenon (Bowen, 2009).

Analysis of data in this study was done as follows:

- Firstly, the lecture videos were watched three times.
- After watching the videos of the lecturer teaching, the lectures were transcribed and labeled according to the concept being taught.
- Transcripts were read repeatedly with careful consideration to correct semantic and grammatical inconsistencies and to make sense of the totality of data.
- Data collected from the interview with the lecturer was transcribed and labeled according to the data collected.
- Interview transcripts were read repeatedly with careful consideration to correct semantic and grammatical inconsistencies and to make sense of the totality of data.
- The narrated PowerPoint presentations were transcribed, and transcripts were read repeatedly with careful consideration to correct semantic and grammatical inconsistencies and to make sense of the totality of data.
- Then the raw data were sorted and coded and the research questions were used to produce a framework for the category.

The analysis was inductive, codes and themes were created by close readings of the text in interview transcripts, lecture transcripts, and narrated PowerPoint presentations to identify text segments that contain meaning units (Thomas, 2003). The inductive content analysis begins with organizing the raw data through a process known as coding. The initial themes and codes were derived from the literature review. The transcribed data was coded. The material was then reviewed. Notes were made and headings were created as the data were reviewed. The next step involved grouping the data and reducing the number of categories by combining similar headings into broader categories. Through this process, the researcher's knowledge was generated, and the understanding of the material was enhanced.

3.8 RELIABILITY AND VALIDITY

Reliability refers to the degree to which measurements are repeatable. That is, the same results are guaranteed when the measurements are performed by different researchers, on different occasions, and under different conditions (Drost, 2011). Validity determines whether the research instrument measures what is intended (Golafshani, 2003). Therefore, the reliability and validity of the data are sustained by the instruments used in the research (Ngonyani, 2018).

This study ensured reliability by using the triangulation method of data collection which included an interview and videorecording data. Also, the supervisor assisted in refining the interview questions, the coding, and the categorization of the codes into themes.

3.9 Ethics

As part of my ethics application, I sent a letter to the WSoE Head of School asking for permission to interview the lecturer. This research had a few ethical considerations. The vital ethical considerations involved the consent of the lecturer who in this case will be the respondent. The researcher requested informed consent regarding the citation of the lecturer, where the lecturer needed to be protected the citations were protected using anonymous citations. The confidentiality of the lecturer's material was acquired through informed consent. Regarding ethical considerations of confidentiality, the researcher acquired informed consent from the tape recorder. The tape recorder is used for note-taking purposes bearing in mind the ethical considerations of confidentiality. All the data acquired will be utilized only for academic purposes.

To ensure the confidentiality of the participants' information, access to the participant's responses and other data will be restricted to the researcher (me) and disposed of via shredding after five years if the researcher sees that there's no further work that needs to be done.

3.10 Conclusion

This chapter has presented the research methodology. Specifically, the chapter has provided the research design, research approach, case study method, participants, and the methods that describe how data was collected in this study, reliability, and validity, and lastly, ethical issues considered in conducting research. The following chapter includes data analysis and a presentation of findings.

CHAPTER FOUR
DATA ANALYSIS, PRESENTATION OF RESULTS AND DISCUSSION

Introduction

The previous chapter outlined the methodology that was utilized to collect the data for this study. This chapter aims to present the analysis of the data that were collected from watching the video recordings of cell biology lectures and discuss the findings. The research questions that guided this study were:

- What teaching strategies does the lecturer use to promote meaning-making when teaching cell biology concepts in an eLearning classroom?
- How does the lecturer use the identified teaching strategies to promote the meaning-making of cell biology concepts?

4.1 Data sources

Data were in the form of video-recorded lectures on the BigBlueButton and an audio-recorded interview with the lecturer. Three lecture sessions were video recorded. One session was on prokaryotic and eukaryotic cells and two were on cell structure and function. A tutorial session was also analyzed. The duration of lecture one was 60 minutes, lecture two was 1 hour and 2 minutes and lecture three was 1 hour and 14 minutes. All three lecture sessions took place on the BigBlueButton on Ulwazi. Lecture one was an introduction to the topic, and it focused on prokaryotic and eukaryotic cells whereas lectures two and three were on cell structure and function.

4.2 Analysis of video-recorded lectures

I familiarized myself with what happened during the lectures that took place on the BigBlueButton (BBB) by watching the video recordings four times. I then transcribed the video recordings by writing down the audio and took screenshot details as sources of evidence. Below is an excerpt of the transcript of lecture one, the rest of the transcript is in Appendix Two.

Student-: Hi, okay… so far, I think a cell is a basic unit of life where the vital processes in the body occur such as metabolism as you mentioned earlier.

Lecturer-: Okay, thank you. Calls another student name. Your hand is up

Student-: Greetings… I think that a cell is a building block of all living things.

Lecturer-: Thank you. What do you mean by that?

Student-: I mean that living things have cells, like cells are monomers of living things. We are created of cells.

Lecturer-: Thank you. Calls another student name. What is a cell? Your hand is up.

Student-: Is the smallest unit that can live on its own and it makes up living organisms and tissues in the body.

Lecturer-: What is a cell?

After transcription was completed, coding of the transcripts was initiated. The method of analysis was inductive, the literature reviewed in Chapter Two guided the analysis in terms of what teaching strategies are and what active engagement entails. After transcription, the literature that was reviewed in chapter two informed how to deduce the different teaching strategies employed by the lecture. Lesson transcripts were analyzed using highlighting texts that symbolize teaching strategies used by the lecturer as shown in section 4.2.

4.2.1 Illustration of analysis of the eLearning teaching strategies.

Question-and-answer eLearning teaching strategy was deduced from the analysis of the three lesson transcripts. When analyzing for and deducing the question-and-answer teaching strategy, I looked for patterns that demonstrated questions posed to the lecturer by students and questions posed to the students by the lecturer, and how the response was conveyed. I then highlighted the questions and responses using codes to observe if a pattern was apparent. In lesson one, the lecturer used a question-and-answer eLearning teaching strategy to introduce the cell via the webcam on the BigBlueButton, he posed a question to the students, "*What is a cell*?" and they responded which demonstrated a dialogue as shown in the excerpt below, thus participation and active engagement can be deduced which promotes meaning-making.

A lesson excerpt that shows: Question-and-answer eLearning teaching strategy

Lecturer-: What is a cell? I have already shown you. What is a cell? **(The lecturer posed a question to the students via the webcam on the BigBlueButton)**

Students raise their hands… **(Participation-student virtually raising their hands on the BigBlueButton)**

Student-: Meneer, from what I have read so far, they say a cell is a basic unit of life. **(The student responds to the question asked by the lecturer via the audio on the BigBlueButton)**

Lecturer-: Okay, it is a basic unit but what is it? (Calls the name of another student). **(The lecturer uses probing to teach, such that he accepts the answer given but asks the question again to obtain a correct answer)**

Student -: Hello Sir and everyone so the cell is the basic unit of the life which means for an organism to live it should have a cell, it is the one that provides a I can say many things for us to live such as protein and all that.

Four more teaching strategies were deduced using the same technique used in the question-and-answer teaching strategy, the teaching strategies are Lecture eLearning teaching strategy, class activities and tutorials eLearning teaching, collaborative student presentations eLearning teaching strategy, and lastly video-based eLearning teaching strategy.

After looking for the teaching strategies, I looked at how each teaching strategy was used to promote meaning-making in the eLearning classroom by looking at how each teaching strategy promotes both participation and engagement. This was done by coding different interactions, techniques, and processes that occurred in the eLearning classroom as either "participation" or "engagement". After coding was complete, an analysis of the frequency of the codes was done. This was done to see the patterns and frequency of both participation and engagement in individual teaching strategies. The frequency of participation and engagement while using each teaching strategy allows us to deduce the dominant teaching strategy(ies) and how it promotes meaning-making.

Table one: The excerpt below shows the analysis of video transcripts to show how technology was used to teach concepts in a way that enhances student learning experiences, by facilitating participation and active engagement thus promoting meaning-making. The TPACK model was used to analyze how teaching strategies promote meaning-making in an eLearning classroom by analyzing the relationship between pedagogical knowledge (to identify the type of teaching strategy), content knowledge, and technological knowledge. TPACK guided this analysis to show how teaching strategies promote meaning-making when technology is integrated into an eLearning classroom. The rest of the table is in Appendix One.

Pedagogical knowledge *(Type of eLearning teaching strategy used by the lecturer)*	**Content knowledge** *(Concept being taught)*	**Technological knowledge** *(The BigBlueButton was used as an online classroom and the lecturer used his laptop to facilitate teaching. It is worth noting that the BigBlueButton can be accessed using electronic devices such as a cellphone, tablet, and laptop)*	How was the teaching strategy used?
1. ***Question-and-answer teaching strategy*** using synchronous communication which includes the chat room, webcam, and audio which are initiated by virtually the raising of hands on the BigBlueButton.	1. Cellular organelles (i.e. Ribosomes, lysosomes, peroxisomes). 2. Cellular organelles (i.e Endoplasmic reticulum)	1. The lecturer used screen share on the BigBlueButton to project a 3D image of an animal cell to facilitate an explanation of the structure and function of cellular organelles ***(eLearning teaching strategy- Lecturer using the webcam video and screen sharing on the BigBlueButton to facilitate the question and answer teaching strategy)*** 2. Students virtually raise their hands on the blue button conference and the lecturer recognizes the student's hands by verbalizing the student's name via the webcam video on the BigBlueButton ***(eLearning teaching strategy- Lecturer using the webcam video and screen sharing on the BigBlueButton to facilitate the question and answer teaching strategy)***	-The student asked the lecturer through the audio feature on the BigBlueButton if the ribosomes are the same organelle as the peroxisomes, and lysosomes ***(Engagement-meaning making-student asking the lecturer a question via the audio feature on the BigBlueButton)*** -The lecturer answered the student through the webcam on the BigBlueButton and explained the biology terminology by explaining how each word was constructed to bring about meaning ***(Engagement-meaning making- Explanation of the content using the webcam video on the BigBlueButton)*** *Student virtually raises their hand* ***(Participation- meaning making-student virtually raising their hand on the BigBlueButton)*** *Lecturer-: Calls the student's name through the webcam on the BigBlueButton* ***(Engagement-meaning making-Lecturer calling the student by***

		3. Students respond synchronously in two ways either by writing their answers in the chat room or by verbalizing their responses through the audio platform ***(eLearning teaching strategy- Lecturer using the webcam video and screen sharing on the BigBlueButton to facilitate the question and answer teaching strategy)***	***name using the webcam video on the BigBlueButton)*** *Student-: Sir, is a peroxisome and lysosome a type of ribosome? Or are they different from ribosomes?* ***(Engagement- meaning students asking the lecturer a question via the audio feature on the BigBlueButton)*** *Lecturer-: those are different organelles. There is something called "some", there is that "some" thing at the end of that common term, some. Some are coming from a term called soma which means body, so those are three different bodies, and the first part you'll find that biological terms, most biological terms are described by a combination of terms so peroxi is one word and some are another word. So, peroxisomes are structures that are built from peroxi and there is a word called somebody. If you hear the word "peroxi", what does it relate to? A substance? **(Engagement-meaning making-Explanation of the content using the webcam video on the BigBlueButton)*** *Student virtually raises their hand* ***(Participation- meaning making-student raising their hand on the BigBlueButton)*** *Student-: peroxide.* ***(Participation-meaning students answering the lecturer's question via the audio feature on the BigBlueButton)*** -The lecturer posed a question to the students regarding the endoplasmic reticulum through the webcam on the BigBlueButton (***Engagement- meaning making-lecturer asking students a question using the webcam video on the BigBlueButton***). The students answered the question the lecturer through the audio feature on the BigBlueButton conference by virtually raising their hands, and others posted

			their answers on the chat platform on the BigBlueButton ***(Participation making- student answering the lecturer's question via the audio feature on the BigBlueButton)*** -As the students answered the questions, the lecturer posed simplified and easier follow-up questions via the webcam on the BigBlueButton. Which resulted in a synchronous discussion on the chat platform and via the audio feature. *Lecturer-: what is the opposite of endo? **(Engagement-meaning making- Lecturer asking students a question via the webcam on the BigBlueButton)*** *Student-: it's Exo **(Participation -making making-student answering the lecturer's question via the audio feature on the BigBlueButton)***

After coding the three lecture transcripts, I extracted all the codes that I had generated and listed them according to whether they promoted participation or engagement which in turn promoted meaning making. Then similar codes were grouped to identify the teaching strategy elucidated by that code. The list of the codes is shown below:

1. ***Engagement-meaning making- student asking the lecturer a question via the audio feature on the BigBlueButton***
2. ***Engagement-meaning making-Lecturer responding to the question posed by the student via webcam on the BigBlueButton***
3. ***Engagement-meaning making- Explanation of the content using the webcam video on the BigBlueButton***
4. ***Participation- meaning making- student virtually raising their hand on the BigBlueButton***
5. ***Engagement-meaning making-Lecturer calling the student by name using the webcam video on the BigBlueButton***
6. ***Engagement- meaning making-student asking the lecturer a question via the audio feature on the BigBlueButton***
7. ***Engagement-meaning making-Lecturer responding to the question posed by the student via webcam on the BigBlueButton***
8. ***Engagement- meaning making-Explanation of the content using the webcam video on the BigBlueButton***
9. ***Participation- meaning making- student raising their hand on the BigBlueButton***
10. ***Participation- meaning making-student answering the lecturer's question via the audio feature on the BigBlueButton***

11. *Engagement- meaning making-lecturer asking students a question using the webcam video on the BigBlueButton*
12. ***Participation-meaning making- student answering the lecturer's question via the audio feature on the BigBlueButton***
13. *Engagement-meaning making- Lecturer asking students a question via the webcam on the BigBlueButton*
14. ***Participation -meaning making-student answering the lecturer's question via the audio feature on the BigBlueButton***
15. ***Engagement- meaning making-explanation of the content via the webcam on the BigBlueButton***
16. *Engagement- meaning making- lecturer asking the students a question via the webcam on the BigBlueButton*
17. ***Participation- meaning making- student virtually raising their hand on the BigBlueButton***
18. ***Participation- meaning making - student answering the lecturer's question via the audio feature on the BigBlueButton***
19. *Engagement- meaning making- lecturer asking the students a question via the webcam on the BigBlueButton*
20. ***Participation-meaning making- student virtually raising their hand on the BigBlueButton***
21. ***Participation- meaning making - student answering the lecturer's question on the audio feature on the BigBlueButton***
22. ***Participation- meaning making - student answering the lecturer's question on the audio feature on the BigBlueButton***
23. ***Participation- meaning making - student answering the lecturer's question on the audio feature on the BigBlueButton***
24. ***Engagement- meaning making-explanation of the content via the webcam on the BigBlueButton***
25. ***Participation-meaning making- student virtually raising their hand on the BigBlueButton***
26. ***Participation- Meaning Making - Student Answering The Lecturer's Question Via The Audio Feature On The Bigbluebutton***
27. ***Engagement- Meaning Making-Explanation Of The Content Using A Projected Image Via The Webcam On The Bigbluebutton***
28. ***Engagement- Meaning Making-Explanation Of The Content Using A Projected Image Via The Webcam On The Bigbluebutton***
29. *Engagement-Meaning Making- Lecturer Asking Students A Question Via The Webcam On The Bigbluebutton*
30. ***Participation-Meaning Making- Student Virtually Raising Their Hand On The Bigbluebutton***
31. ***Participation- Meaning Making-Student Answering The Lecturer's Question Via The Audio Feature On The Bigbluebutton***
32. ***Engagement-Meaning Making- Lecturer Validating The Student's Response Via The Webcam On The Bigbluebutton***
33. ***Participation- Meaning Making-Student Asking The Lecturer A Question On The Chat Platform On The Bigbluebutton***
34. ***Engagement-meaning making-Lecturer responding to the question posed by the student via webcam on the BigBlueButton***
35. *Engagement -Lecturer Asking Students A Question Via The Webcam On The Bigbluebutton*

36. *Participation-Meaning Making- Student Virtually Raising Their Hand On The Bigbluebutton*
37. *Participation- Meaning Making-Student Answering The Question Posed By The Lecturer Via The Audio Platform On The Bigbluebutton*
38. *Engagement- Meaning Making-Explanation Of The Content Using A Projected Image Via The Webcam On The Bigbluebutton*
39. *Engagement- Meaning Making-Lecture Facilitating An Activity On The Bigbluebutton*
40. *Participation-Meaning Making- Student Answering The Question Via The Audio And Chat Platform On The Bigbluebutton*
41. *Engagement- Meaning Making-Lecturer Asking Students Questions Via Webcam On The Bigbluebutton*
42. *Engagement- Meaning Making-Lecture Facilitating An Activity On The Bigbluebutton*
43. *Participation-Meaning Making- Student Virtually Raising Their Hand On The Bigbluebutton*
44. *Participation-Meaning Making- Student Answering The Question Via The Audio Platform On The Bigbluebutton*
45. *Engagement – Meaning Making-Lecturer Asking A Follow-Up Question Via The Webcam On The Bigbluebutton*
46. *Participation-Meaning Making- Student Virtually Raising Their Hand On The Bigbluebutton*
47. *Participation-Meaning Making- Student Answering The Question Via The Audio Platform On The Bigbluebutton*
48. *Engagement- Meaning Making- Lecturer Giving Students A Task Via The Tutorial Pole On The Bigbluebutton*
49. *Participation – Meaning Making -Students Responded By Drawing The Plant Cell On The Tutorial Pole Via The Bigbluebutton)*
50. *Engagement- Meaning Making-Lecturer Guiding Students On How To Improve Their Drawing Via The Webcam On The Bigbluebutton*
51. *Participation- Meaning Making-Students Responding To Drawings On The Tutorial Pole*
52. *Engagement –Meaning Making- Lecturer Giving Students A Task Via The Webcam On The Bigbluebutton*
53. *Participation -Meaning Making-Student Posting A Drawing Of The Plant Cell On The Tutorial Pole Via The Bigbluebutton*
54. *Engagement- meaning making-lecturer guiding students on how to improve their drawing via the webcam on the BigBlueButton*
55. *Participation-meaning making- students presenting cell organelles via screenshare and audio on the BigBlueButton*
56. *Engagement-meaning making- lecturer used the student presentation to explain cellular organelles via the webcam on the BigBlueButton*
57. *Participation-meaning making- students presenting cell organelles via screenshare and audio on the BigBlueButton*
58. *Participation-meaning making- students presenting cell organelles via screenshare and audio on the BigBlueButton*
59. *(Participation-meaning making- students presenting cell organelles via screenshare and audio on the BigBlueButton)*
60. *Engagement-meaning making- lecturer tells students to take notes via the webcam on the BigBlueButton*

61. *Participation-meaning making- student virtually raising their hand on the BigBlueButton*
62. ***Participation-meaning making- student elaborates on what the lecturer has stated on the audio platform via the BigBlueButton***
63. *Engagement-meaning making- lecturer using student presentation to explain cellular organelles via the webcam on the BigBlueButton*
64. *Engagement-meaning making- lecturer using student presentation to explain cellular organelles via the webcam on the BigBlueButton*
65. *Engagement-meaning making- lecturer using student presentation to explain cellular organelles via the webcam on the BigBlueButton*
66. *Participation -meaning making- student responding to the lecturer's explanation on the audio platform via the BigBlueButton*
67. *Participation-meaning making- student virtually raising their hand on the BigBlueButton*
68. *Participation- meaning making- student asks a question regarding the video that was played on the audio platform via the BigBlueButton*
69. *Engagement- meaning making-lecturer asking students a question via the webcam on the BigBlueButton*
70. *Participation- meaning making-student answer the question posed by the lecturer via the audio platform on the BigBlueButton*
71. *Engagement- meaning making-lecturer asking students a question via the webcam on the BigBlueButton*
72. *Participation- meaning making-student answer the question posed by the lecturer via the audio platform on the BigBlueButton*
73. *Engagement-meaning making-Explanation of the content via the webcam on the BigBlueButton*
74. *Engagement-meaning making-lecturer giving students a task based on the video via the webcam on the BigBlueButton*
75. ***Engagement-meaning making-Lecturer responding to the question posed by the student via webcam on the BigBlueButton***

71 codes were generated at the end, during the analysis of the codes, similar codes were observed and color-coded as part of the processing of the codes. For example, when the engagement was promoted by the lecturer asking students a question, the color grey was used: Engagement- *meaning making-lecturer asking students a question via the webcam on the BigBlueButton*

Table two below is a frequency table showing the recurrence of the codes during the analysis of the transcripts.

Code	Frequency
Engagement-meaning making- student asking the lecturer a question via the audio feature on the BigBlueButton	3
Engagement-meaning making- Explanation of the content using the webcam video on the BigBlueButton	12
Participation- meaning making- student virtually raising their hand on the BigBlueButton	11
Engagement-meaning making-Lecturer calling the student by name using the webcam video on the BigBlueButton	1

Participation- meaning making-student answering the lecturer's question via the audio feature on the BigBlueButton	17
Engagement- meaning making- lecturer asking the students a question via the webcam on the BigBlueButton	10
Engagement-meaning making-lecturer giving students a task based on the video via the webcam on the BigBlueButton	6
Participation-meaning making- students presenting cell organelles via screenshare and audio on the BigBlueButton	5
Participation – Meaning Making -Students Responded By Drawing The Plant Cell On The Tutorial Pole Via The Bigbluebutton)	3
Engagement-meaning making-Lecturer responding to the question posed by the student via webcam on the BigBlueButton	3

Table two demonstrates that the **question-and-answer eLearning teaching strategy** was dominant, with a frequency of 23 for "***Engagement-meaning making- student asking the lecturer a question via the audio feature on the BigBlueButton"*** and 17 for ***"Participation-meaning making-student answering the lecturer's question via the audio feature on the BigBlueButton"***. The frequency that is shown in the table demonstrates that this teaching strategy was used often during the teaching and learning of cell biology in an eLearning classroom.

After color-coding all the codes, they were grouped and from the grouped codes a total of five themes were developed. The themes describe how the teaching strategies promote participation and engagement which are the key hallmarks of meaning-making. The five themes are listed below:

1. ***The question-and-answer eLearning teaching strategy was used to promote participation and engagement which promoted meaning-making in an eLearning classroom.***

The codes below were grouped into the theme of "Question-and-answer eLearning teaching strategy".

- ✔ ***Engagement-meaning making- student asking the lecturer a question via the audio feature on the BigBlueButton***
- ✔ ***Engagement-meaning making-Lecturer responding to the question posed by the student via webcam on the BigBlueButton***
- ✔ ***Participation- meaning making-student answering the lecturer's question via the audio feature on the BigBlueButton***
- ✔ ***Engagement- meaning making- lecturer asking the students a question via the webcam on the BigBlueButton***

2. ***Explaining as an eLearning teaching strategy was used as a tool to facilitate understanding, and discussion which promoted engagement which promoted meaning-making.***

The code below was grouped into the theme of "Explaining as an eLearning teaching method".

- ✔ ***Engagement-meaning making- Explanation of the content using the webcam video on the BigBlueButton***

3. ***Class activities and tutorials were used as an eLearning teaching strategy to facilitate reasoning and develop cognitive skills which promoted engagement.***

The codes below were grouped into the theme of "Class activities and tutorials were used as a teaching strategy to facilitate reasoning and develop cognitive skills which promoted engagement".

- ✔ ***Engagement-meaning making-lecturer giving students a task based on the video via the webcam on the BigBlueButton***
- ✔ ***Participation – Meaning Making -Students Responded By Drawing The Plant Cell On The Tutorial Pole Via The Bigbluebutton)***

4. ***Collaborative student presentations as an eLearning teaching strategy were used to stimulate engagement in an eLearning classroom by promoting learning through guidance and collaboration.***

The codes below were grouped into the theme of "Collaborative student presentations as an eLearning teaching strategy was used to stimulate engagement in an eLearning classroom by promoting learning by guidance and collaboration".

- ✔ ***Participation-meaning making- students presenting cell organelles via screenshare and audio on the BigBlueButton***
- ✔ ***Participation-meaning making- student elaborates on what the lecturer has stated on the audio platform via the BigBlueButton***

5. ***Video-based eLearning was used as an eLearning teaching strategy to promote visualization which facilitates participation and engagement.***

The codes below were grouped into the theme of "Video-based learning was used as an eLearning teaching strategy to promote visualization which facilitates engagement".

- ✔ ***Participation- meaning making- student asks a question regarding the video that was played on the audio platform via the BigBlueButton***
- ✔ ***Engagement-meaning making-lecturer giving students a task based on the video via the webcam on the BigBlueButton***

Themes were therefore inductively generated from the analysis. In the next section, findings are presented according to the five themes.

4.3 Presentation of results

4.3.1 What teaching strategies does the lecturer use to promote meaning-making when teaching cell biology in an eLearning classroom?

The analysis of the three video-recorded lectures on the BigBlueButton showed that the lecturer used a variety of teaching strategies that are presented in the following sections.

A. <u>Question and answer eLearning teaching strategy</u>

Drawing from Table two the question-and-answer eLearning teaching strategy was the dominant teaching strategy across the three lectures observed. The lecturer used this eLearning teaching strategy when introducing concepts, gauging the learner's prior knowledge, and using the strategy as a form of summative assessment to check if the students understood the concepts being taught and "how much" of the content they understood. For example, in lecture two a student posed a question to the lecturer via the audio platform in the BigBlueButton and the lecturer responded via the webcam on the BigBlueButton.

Table 3 showing an excerpt of the Question-and-answer eLearning teaching strategy.

Student-: Sir, is a peroxisome and lysosome a type of ribosome? Or are they different from ribosomes? **(Student seeking clarification by asking a question)**
Lecturer-: those are different organelles. There is something called "some", there is that "some" thing at the end of that common term, some. Some is coming from a term called soma which means body, so those are three different bodies, and the first part you'll find that biological terms, most biological terms are described by a combination of terms so peroxi is one word and some is another word. So, peroxisomes are structures that are built from peroxi and there is a word called somebody. If you hear the word "peroxi", what does it relate to? A substance? **(Lecturer answering the student's question)**
Student-: peroxide. **(Student answering a question posed by the lecturer)**

Explanation as an eLearning teaching strategy was used to describe cell biology concepts in a manner that clarifies the reasons, causes, context, or principles that underpin a particular phenomenon. In lecture one, the lecturer used a PowerPoint presentation via screenshare and webcam on the BigBlueButton to communicate their knowledge to describe what are viruses and to use the concept of viruses to provide an example of acellular organisms. Through using a lecture, the lecturer was able to differentiate between cellular and acellular organisms. He referred to the concept of mitosis which is a form of cellular reproduction to illustrate that viruses are not living organisms. He was then able to distinguish between prokaryotic and eukaryotic organisms by explaining using cellular structure. See the excerpt in Table 4 below (the rest is in Appendix two):

Table 4 below shows the : Explanation as an eLearning teaching strategy

Lecturer-: Viruses are microscopic structure, but they are not organisms. How do viruses multiply? They cannot multiply on their own… Your cells can reproduce by mitosis but if you want to mix yourself, viruses cannot mix themselves they go into the host cell to multiply. That is why viruses cannot reproduce they are only two features that may link viruses to characteristics of life. That one of reproduction. Many people want to say viruses reproduce, they don't. The other one is sensitivity; I mentioned this last time that viruses are sensitive because of the proteins on them. Recognition proteins that recognise the host so they can attack a particular host. These are the two features that could cause one to argue that viruses are living but they aren't, they are acellular in nature… **(Lecturer explaining the biology of viruses to the student)**

When analyzing class activities and tutorials as an eLearning teaching strategy I looked for tasks given to the students by the lecturer. The tasks promoted engagement because students had to do the tasks individually and then present the task using screen sharing and the audio platform on the BigBlueButton to the lecturer and other students. In lecture one, the lecturer used a 2D image of an animal cell to verbalize an explanation about the structure of an animal and then gave students a task via the webcam on the BigBlueButton to gauge their understanding. The task entailed "*What would you like your students to know about an animal cell*", in this task students explained the structure of an animal cell in their own words and based on their understanding thus promoting engagement. Consequently, a tutorial was analysed on the chat platform on the BigBlueButton, the lecturer asked students to make a biological … of a plant cell via the webcam on the BigBlueButton and students responded by drawing cells and posting them on the tutorial pole on the BigBlueButton where the lecturer responded to the drawings via the webcam on the BigBlueButton. See the excerpt Table 5 showing :Explanation as an eLearning teaching strategy below:

Table 5 showing :Explanation as an eLearning teaching strategy

Lecturer-: I would like you to post pictures of your plant cell drawings and make comments on those from your colleagues. This is just a practice activity and is not assessed **(lecturer facilitating an activity by asking student to draw a plant cell)** Student 02-: Here is my plant cell drawing. **(students responding by drawing a plant cell)** Lecturer-: Thank you. How many cells were drawn? How correct is this drawing? **(lecturer responding to the students drawing)**

C. Collaborative student presentations as an eLearning teaching strategy

In lecture two, the lecturer facilitated group work through student presentations to teach cell structure and function via webcam on the BigBlueButton. Students presented on different cellular organelles via the audio platform on the BigBlueButton, and after the presentation, students asked questions to obtain clarification on the concepts, they did not understand via the audio platform on the BigBlueButton. The lecturer then responded by providing a detailed explanation of the content which provided clarity. The explanation also included an analogy so that students can be able to conceptualize the content.

It is noted that the group work that was facilitated through student presentations was used to promote engagement which promotes meaning-making. Students were active participants in their learning as they had to create a PowerPoint presentation that had diagrams and information on the organelle and present it to the class using screen share and the audio

feature on the BigBlueButton. Participation and engagement were promoted by this eLearning teaching strategy as the students researched and educated themselves for every organelle before they presented it to the class, they then mastered the organelles and learned how to describe their functions using their own words. In lecturer three the lecturer used one of the students' presentations to elicit a detailed explanation via the webcam on the BigBlueButton as shown in Table 6 below.

Table 6 showing Collaborative student presentations as an eLearning teaching strategy

Student projects PowerPoint presentation via screenshare on the BigBlueButton

Student presenter 3-: Good morning to my fellow students. I'm the presenter for my group. These are the names of my group members. First, I would like to take you through the content of our definition, region, structure, functions, and diagrams and share recommendations where you can get more information about the centriole. First, we are going to talk about the definition of a centriole, I have a diagram with me whereby you can see the structure, and another structure here is the animal cell. Centrioles are two cylindric, rod-shaped microtubular structures, near the nucleus. They are not present in the prokaryotes, red algae, yeast, cone-bearing, and high flower plants, and also, non-flagellated or ciliated protozoans (such as amoebae). Centriole form a spindle of microtubules, the mitotic apparatus during mitosis or meiosis, and sometimes get arranged just beneath the plasma membrane to form and bear flagella or Cilla in flagellated or ciliated cells. Thank you, next slide, ***(student presenting a cellular organelle)***

In lecture one the lecturer used a video via screen sharing on the BigBlueButton for visualization and explanation of the structure and function of cells. The video was used as a form of animation whereby verbal cues were incorporated into images. Thus, this promoted participation as students asked questions after the video was played and the lecturer responded by providing clarity. Clarity was elicited in the concise and detailed responses given by the lecturer.

[Lecturer plays a video on prokaryotic cells] ***(lecturer facilitating a lesson by using a video)***

Student raises their hand

Student-: Sir, I would like to know what he meant when he said that the cell wall and cell membrane contain something what do they contain ***(student asks a question regarding the video that was played on the audio platform via the BigBlueButton)***

Lecturer-: Saccharides are sugars. Cell walls are mainly made of polymers of sugars and other substances such as murrain. We'll get there, what we were talking about…. When we talk about the differences between cells, we are highlighting the differences between living things. When we are identifying organisms as prokaryotic, we are grouping them into two large groups. One group is prokaryotic organisms then another huge group is eukaryotic ***(Explanation of the content via the webcam on the BigBlueButton)***

4.3.2 How do the identified teaching strategies used by the lecturer promote the meaning-making of cell biology concepts?

1. The lecturer used the question-and-answer eLearning teaching strategy to teach biological terms, cellular organelles, and cell structure and function.

The analysis of the video recording of lecture two of the BigBlueButton (refer to the Appendix and the illustration section presented earlier) showed that the question-and-answer interaction between the lecturer and students is used to stimulate participation which then promotes engagement. For example, in lecture two when a student asked the lecturer '*Sir, is a peroxisome and lysosome a type of ribosome? Or are they different from ribosomes?' **(Engagement- meaning making- student asking the lecturer a question via the audio platform on the BigBlueButton)***. The way the question was phrased showed that the student is observant of the similarities of these three words and that there is a lack of understanding of the cell biology terminology. However, the lecturer constructed the answer to the student by firstly stating that '*those are different organelles.* This statement nullifies the observation made by the student; however, the lecturer continues by explaining **WHY** he says they are different organelles by saying '*There is something called "s-o-m-e", there is that "s-o-m-e" thing at the end of that common term, s-o-m-e. Some come from a term called soma which means body, so those are three different bodies, and the first part you'll find that biological terms, most biological terms are described by a combination of terms so peroxi is one word and s-o-m-e is another word' **(Engagement- meaning making-Explanation of the content by the lecturer via the webcam on the BigBlueButton)***. This kind of explanation whereby the lecturer is dissembling biological terms and explaining them provides a deeper understanding of cell biology terminology thereby facilitating understanding and concurrently encouraging engagement.

The lecturer concludes by posing a question to the students, now he poses a simpler question that is guided thereby guiding students to a more correct answer. '*So, peroxisomes are structures that are built from peroxi and there is a word called soma body. If you hear the word "peroxi", what does it relate to? A substance?' **(Engagement-meaning making-lecturer asking students a question via the webcam on the BigBlueButton)***. The student then verbalizes their response '*peroxide'* ***(Participation: meaning-making- student answering the lecturer's question via the audio platform on the BigBlueButton)***. By verbalizing the response of the meaning of peroxi, not only was the meaning shared on the social plane (Vygotsky, 1987) with the rest of the students, but other students were able to make sense of the word 'peroxisome' since the lecturer had already defined 'soma' as body and now with the student saying 'peroxide', students can see the difference between the three structures. Therefore, the teaching strategy of question-and-answer allowed students to ask questions through the audio platform on the BigBlueButton based on the information they were given to gain deeper meaning, thereby promoting engagement and the lecturer to formulate explanations and pose simpler and guided questions where students were allowed to answer thereby promoting participation and engagement thus facilitating meaning-making.

2. The lecturer used explanation as a teaching strategy to explain the structure of an animal cell and clarify concepts that promoted engagement

The analysis of the lecture three video recording of the blue button showed that explanations were facilitated by the lecturer to explain the structure of a chloroplast, which promotes participation and engagement. The lecturer used a projected 3D image of a chloroplast to explain the structure and function of the chloroplasts through screen sharing and webcam on the BigBlueButton. Students were able to visualize the structure of the chloroplast on their screens via the BigBlueButton as the lecturer was explaining how the structure is adapted to its function which facilitated engagement. Students then participated via the audio platform on the BigBlueButton by explaining the process of photosynthesis in their own words.

(Lecturer projects a 3D image of a chloroplast with notes)

Lecturer-: Thank you very much I would like to emphasize this diagram. (The projected 3D diagram of a chloroplast). In this slide, we need to start with structure and then go into function. Before we talk about the functions the learners need to know the structure and not upside down. ***By making this statement, the lecturer verbalizes the importance of understanding the structure of an organelle that is projected via screen sharing on the BigBlueButton.***

(Projects a colored and labeled 3D diagram of a chloroplast)

[The lecturer describes the structure of the chloroplast by explaining the components found inside the chloroplast and relating the components to each other.] *There will be other enzymes necessary for life, but the key enzymes found in the stroma are those responsible for photosynthesis. Particularly dark reactions of photosynthesis. Photosynthesis takes place in two phases, one light-dependent phase and the other one is light-independent phase* ***(Engagement-meaning making-Explanation of the content using a projected image through the webcam on the BigBlueButton)****. So, the light-dependent phase takes place inside the thylakoids and the light-independent stage or phase is enzyme-driven it doesn't require light. It takes place inside the stroma. Anyone who can help me distinguish between these two, light-dependent and light-independent? What do we mean?* ***(Engagement-meaning making-lecturer asking students a question through the webcam on the BigBlueButton).***

Student-: when you say something is light dependent, it depends on light to produce or do whatever all its functions but when it's independent of light it does not depend on light. It can occur in a dark phase. That's my understanding. **[Participation-meaning The student answers the question posed by the lecturer in their own words, it is explaining concepts in your own words as a student that enables the student to develop clarity in their understanding thus enabling meaning-making.]**

3. Class activities and tutorials teaching strategy was used to stimulate engagement in an eLearning classroom

The analysis of the lecture one video recordings showed that tutorials and activities teaching strategies were used to stimulate engagement in an eLearning classroom. For example, when the lecturer asked students to draw a labeled 2D diagram of a plant cell ***(Engagement-meaning making- lecturer giving students a task)***, the students responded by drawing and posting the drawings on the tutorial component in uLwazi ***(Participation- meaning making-students responded by drawing the plant cell and posting the drawing on the tutorial pole on the BigBlueButton)***. The lecturer then gave feedback on the drawings

(Engagement- meaning making-lecturer guiding students on how to improve their drawing through the webcam on the BigBlueButton).

Lecturer-: I would like you to post pictures of your plant cell drawings and make comments on those from your colleagues. This is just a practice activity and is not assessed ***(Engagement- meaning making- lecturer giving students a task through the webcam on the BigBlueButton)***

Student 01-: Here's my plant cell ***(Participation- meaning making-students responded by drawing the plant cell and posting the drawing on the tutorial pole on the BigBlueButton)***

Lecturer-: Thank you. Reflecting on the lesson yesterday on the cow, what was done well, and what could be improved on this diagram? ***(Engagement- meaning making-lecturer guiding students on how to improve their drawing through the webcam on the BigBlueButton)***

The teaching strategy promoted engagement because when the lecturer instructed students to draw through the webcam on the BigBlueButton, they responded by drawing and posting 2D images on the tutorial pole on the BigBlueButton. The lecturer was able to engage students to learn the structure of the plant cell by using a drawing activity. When students posted their drawings on the tutorial pole on uLwazi the lecturer gave feedback and commented on how the activity was supposed to be conducted ***(Engagement- meaning the making-lecturer guiding students on how to improve their drawing through the webcam on the BigBlueButton)***. The guidance the lecturer provided made it easy for students to make clear drawings of the organelles. However, also students gave feedback on the drawings made which encouraged participation which encouraged engagement.

The activity showed the importance of effective guidance in assisting students in constructing knowledge. Students made the drawings individually, this facilitated active learning. Each learner was an active participant in their learning. Students provided labels for their drawings; this helped them to relate the terminology of cell biology to the structures. Because each learner conducted this activity individually, this allowed each learner to construct personalized meanings of the cell biology terms. Therefore, the use of a drawing activity in an online classroom promotes engagement which promotes meaning making.

4. Collaborative students' presentations in an eLearning classroom were used as a teaching strategy to stimulate engagement in the classroom by promoting learning through guidance and collaboration.

The analysis of the lecture three video recording showed that the lecturer used students' presentations to facilitate learning through guidance and collaboration on the BigBlueButton. The students presented on cellular organelle structure and function using screen sharing and the audio platform on the BigBlueButton ***(Participation-meaning making- students presenting cell organelles via screen share and audio on the BigBlueButton)*** and the lecturer used their presentations to guide the students on what they should know regarding the presented organelle and how to teach and construct the lesson (***Engagement-meaning making- lecturer using student presentation to explain cellular organelles via the webcam on the BigBlueButton).*** The presentations were done in groups.

Student presenter 3-: Good morning to my fellow students. I'm the presenter for my group. These are the names of my group members. First, I would like to take you through the content of our definition, region, structure, functions, and diagrams and share recommendations where you can get more information about the centriole (could this be engagement as it directs students on what to be attentive to?). First, we are going to talk about the definition of a centriole, I have a diagram with me whereby you can see the structure, and another structure here is the animal cell. Centrioles are two cylindric, rod-shaped microtubular structures, near the nucleus. They are not present in the prokaryotes, red algae, yeast, cone-bearing, and high flower plants, and
also, non-flagellated or ciliated protozoans (such as amoebae). Centrioles form a spindle of microtubules, the mitotic apparatus during mitosis or meiosis, and sometimes get arranged just beneath the plasma membrane to form and bear flagella or cilia in flagellated or ciliated cells. Thank you, next slide, ***(Participation-meaning making- students presenting cell organelles via screenshare and audio on the BigBlueButton)***

Lecturer-: thank you very much, sorry you could not present from that side I also had a challenge here. What is interesting is that this is an animal cell organelle, it is only found in animal cells. You must take note of that because we are going to ask you where these organelles are found and where they are not found ***(Engagement-meaning making- lecturer tells students to take note)*** **[The lecturer makes an important input regarding the difference between a plant and animal cell from the student presentation and further promotes engagement when he verbalizes the instruction of note-taking by the students via webcam on the BigBlueButton]**

Student presenter 3-: okay sir, on that on which these organelles are not found I think I've mentioned in the origin where I said they are not found in the prokaryotes, algae, and other high plants. They are not present there; I don't know if anyone is having a challenge in understanding that ***(Participation- meaning making-student elaborates on what the lecturer has stated)***

[The student then elaborates on the concept stated by the lecturer]

Lecturer-: Yes, thank you. We… that's what I'm emphasizing when we are going to ask you questions in exams, we are going to ask you where they are found and where they are not found, and we may ask you about the structure and function as well.: so, centrioles ***(Participation- meaning making-student elaborates on what the lecturer has stated)***

The lecturer then guided the students on why he stated that they should take notes.

(Lecturer projects a 3D image of centrioles)

I'm projecting this image because it's speaking to a structure, I want you to know and understand. The centrioles exist in pairs, and their units are always at right angles to each other all the time there are two centrioles, they are sitting at right angles to each other. Please don't ask me why I don't know why but this is how they are always. It's not like this diagram has been made for two different centrioles but this structure you are seeing here is describing one set of centrioles. Every time you indicate a centriole in a cell you are referring to a pair, two of them when they are together and these two for each one of them, have nine triplets of microtubules there are three that form a triplet and there will be nine of them on

*the outside….(**Engagement-meaning making- lecturer using a projected image to explain cellular organelles via the webcam on the BigBlueButton)***

[The lecturer used a projected image via screen sharing on the BigBlueButton to aid visualization and verbalized the explanation so that students could understand concepts better. He used the projected image to aid with distinguishing between centrioles and centrosomes, he further described what they are made up of and why they are structured the way they are structured. It is in verbalizing the structural components on a social plane using a visual aid, that students can understand the importance of how structure relates to function.]

The lecturer was able to engage students to learn about the structure of the cell by using presentations, the guidance the lecturer provided made it easy for students to comprehend cell structure and function. Students presented organelle structure and function in groups which facilitated learning by collaboration thus facilitating active learning and shared meaning on a social plane. When the students were done presenting the lecturer explained the content in a detailed way which enabled students to ask questions and promoted engagement.

5. Video-based learning as a teaching strategy in an eLearning classroom was used to stimulate engagement by facilitating explanations.

The lecturer used a video on prokaryotic cells in lecture three to facilitate an explanation. The projected video via screen sharing on the BigBlueButton enabled the lecturer to explain cell biology concepts. For example, when the lecturer projected a video on prokaryotic cells via screen sharing on the BigBlueButton, he explained the concepts of saccharides using the projected video (see Appendix Two).

*Lecturer-: Saccharides are sugars. Cell walls are mainly made of polymers of sugars and other substances such as murine. We'll get there, what we were talking about…. When we talk about the differences between cells, we are highlighting the differences between living things. When we are identifying organisms as prokaryotic, we are grouping them into two large groups. One group is prokaryotic organisms then another huge group is eukaryotic **(Engagement-meaning making-Explanation of the content via the webcam on the BigBlueButton)***

The choice of this teaching strategy enabled the lecturer to help students construct knowledge by explaining the structure of prokaryotic cells. The incorporation of detailed explanations after the video made it possible for students to make meaning and build schemas based on what they know, what they have observed from the video, and what the lecturer is explaining. The lecturer was able to facilitate an explanation while directing the focus of the students.

The incorporation of verbal information (explanation) when projecting a video of a prokaryotic cell via screen share on the BigBlueButton: Firstly, encouraged students to listen attentively while posting questions on the discussion pole ***(Engagement: meaning-making-student asking the lecturer a question)*** and secondly students were encouraged to participate in answering the lecturer's question that he posed after he was done explaining. The projected video of a prokaryotic cell enabled the lecturer to explain thereby assisting students in constructing knowledge. Furthermore, the lecturer used the projected

video to facilitate a question-and-answer session thereby promoting participation which encourages engagement.

4.4 Summary

In summary, in this chapter, collected data was presented and analyzed then the findings were discussed. The analysis has identified the teaching strategies that are used by the lecturer when teaching cell biology in an eLearning classroom and how the teaching strategies were used to promote meaning-making in the teaching of cell biology in an eLearning classroom.

The analysis showed that the following types of teaching strategies were used, question and answer, explanation, class activities and tutorials, collaborative student presentations, and lastly video-based learning. While the findings show that these teaching strategies can promote engagement, strategies such as class activities and tutorials can be used in the context of a contact classroom. They can be used in a context classroom because every learner becomes an active participant in their learning when they draw or write notes, therefore we can be certain that meaning-making is promoted when an individual learner works on their own. In all the evident teaching strategies, the lecturer used engagement and participation to promote meaning-making.

4.5 Conclusion

The nature of the teaching strategy alone cannot contribute to engagement and thus promote meaning-making, it is the combination of the verbal cues (spoken words) of the lecturer and the teaching methodology employed that promotes engagement and meaning-making. The findings show us how teaching strategies that incorporate multimodalities such as visuals and verbal cues (spoken words) can be used to enhance knowledge acquisition, learning, and understanding. In the next chapter, which is the concluding chapter, these findings are discussed, and conclusions are drawn.

CHAPTER FIVE
DISCUSSION OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

Introduction

This chapter presents a discussion of the findings, summary, and conclusions of the study. Lastly, recommendations are made for further studies on the use of teaching strategies that promote meaning-making when teaching Cell biology in an eLearning classroom.

5.1 Findings

This study investigated teaching strategies that promote meaning-making in the teaching and learning of cell biology concepts in an eLearning classroom. The questions that guided this study were:

- What teaching strategies does the lecturer use to promote meaning-making when teaching cell biology concepts in an eLearning classroom?
- How are the identified teaching strategies used by the lecturer to promote the meaning-making of cell biology concepts?

5.1.1 **KEY FINDING 1:** *It is possible to use a variety of teaching methods to promote meaning-making on an eLearning teaching and learning platform.*

The lecturer used question and answer, explanations, class activities and tutorials, collaborative student presentations and video-based eLearning teaching strategies across all the lectures observed, and the question and answer eLearning teaching strategy was dominant across the three lectures observed.

The teaching of cell biology in an eLearning classroom requires one to have basic knowledge of good eLearning teaching strategies to enable mastery of cell biology concepts and skills (Zittouni & Brinkmann, 2012). (Gumbo, 2017) postulates that the use of several eLearning teaching strategies accommodates students' diverse learning styles and meets the learning intentions of teaching lessons. In this study, different eLearning teaching strategies were used by the lecturer to teach cell biology in an eLearning classroom, and these eLearning teaching strategies included question and answer, explanations, class activities and tutorials, collaborative student presentations, and video-based learning (see Sections 4.3). The presentation of results in chapter four showed that these teaching strategies were used to engage learners in different ways, thus promoting meaning-making differently.

The several eLearning teaching strategies had an impact on the development of the cognitive abilities of students, as they incorporated problem-solving, active teaching, individualized instruction, task teaching, and lastly visualization (Nielsen & Gutiérrez, 2021).

The question-and-answer eLearning teaching strategy was dominant across the three lectures observed (see sections 4.2 "Table 2- the frequency table"). (Gumbo, 2017) postulates that the use of question and answer as an eLearning teaching strategy is said to be a core function of both learning and teaching. In the eLearning classroom, the lecturer used the

question-and-answer eLearning strategy to gauge what students understand about the concept of cell biology, design the curricular and instructional activities, and lastly facilitate interactions (Nielsen & Gutiérrez, 2021).

The lecturer used the question-and-answer eLearning teaching strategy to introduce new concepts of cell biology and gauge what students understand about the concept of cell biology, that is the lecturer was attempting to understand both the student's prior knowledge and design the curricular and instructional activities, and lastly facilitate interactions which promoted meaningful learning (Vallori, 2014).

During the teaching and learning of cell biology, the question-and-answer eLearning teaching strategy was used to promote participation by creating a dialogue between the lecturer and students as well as engaging students. This was evident when students asked the lecturer whether "a peroxisome and lysosome is a type of ribosome" and the lecturer responded by explaining the background of the meaning of the words thereby promoting meaning-making by facilitating engagement. See the extract below (See section 4.3.1 Table 3).

Table 3 showing an excerpt of the Question-and-answer eLearning teaching strategy.

Student-: Sir, is a peroxisome and lysosome a type of ribosome? Or are they different from ribosomes? ***(Engagement-meaning making-student asking the lecturer a question via the audio feature on the BigBlueButton)***
Lecturer-: those are different organelles. There is something called "some", there is that "some" thing at the end of that common term, some. Some is coming from a term called soma which means body, so those are three different bodies, and the first part you'll find that biological terms, most biological terms are described by a combination of terms so peroxi is one word and some is another word. So, peroxisomes are structures that are built from peroxi and there is a word called somebody… ***(Engagement- meaning making-Explanation of the content using the webcam video on the BigBlueButton)***

According to (Powell & Kalina, 2009), meaning-making predominantly takes place in a social setting like a classroom thus it becomes central that the lecturer creates an environment that is conducive to learning. This can be achieved when students understand their role in the social plane as participants. Active participation involves dialogue where discourses like language, words, and speech are used to promote meaning-making because it is in a dialogue where concepts, subjectivities, perspectives, and judgments can be confronted (Powell & Kalina, 2009). That is, during the lecture both the students and the lecturer engaged in a dialogue to discuss cell biology concepts to clarify misconceptions and understand terminology and cell biology concepts (Vallori, 2014). Therefore, it can be argued that it is in a dialogue that information is conveyed, references are made clear, and most importantly thoughts are implied which promotes mental scaffolding (Powell & Kalina, 2009).

The question-and-answer eLearning teaching strategy also promoted engagement whereby students asked the lecturer questions based on what the lecturer was explaining which denotes active engagement (Martin & Bolliger, 2018). Thus, the question-and-answer eLearning teaching strategy enabled interaction, where students interacted virtually with their lecturer and classmates (Martin & Bolliger, 2018). Interaction enables communication which creates a platform whereby ideas are shared on a social plane before they are internalized by the individual student which promotes meaning-making (Powell & Kalina, 2009). Therefore, Zittouni (2012) postulates that this strategy can promote higher-order thinking through the

use of explanations that are intrigued by high-level questioning which promotes meaning-making (see section 2.2).

The lecturer coupled video-based learning with the question-and-answer teaching strategy as well as the explanation teaching strategy. The use of multimedia enabled the lecturer to provide verbal explanations of a defined segment of information to a large group of students in a short time. The major advantage of explanations coupled with images and videos is that students can visualize what is being explained and that it caters to students with different learning styles (Martin & Bolliger, 2018). However, according to Gumbo (2017), the explanation strategy has a weakness in the teaching of cell biology since it is limited to memory learning and treats students as passive recipients. Zittouni (2009) argues that students learn better if they are actively engaged.

Therefore, it can be deduced that the study of meaning-making requires a need for teaching strategies that lay on a continuum of high student participation and control as well as high teacher participation and control (Ruetenik, 2008). Literature advocates for active participation in meaningful learning, Zittouni (2012) argues that active participation shows engagement, and it is through engagement that meaningful learning can take place. It is observed in this study that when teaching methods that lay on this continuum are used, meaning-making is promoted in an eLearning classroom.

The study of cell biology is an abstract concept where students cannot see this phenomenon in their everyday lives, therefore it requires the teacher to have a repertoire of appropriate eLearning teaching strategies (Ellinger & Ellinger, 2014). The use of eLearning teaching strategies interchangeably during a lesson enables the mastery of cell biology concepts and skills (Ruetenik, 2008). For example, it was observed in the lectures that the lecturer coupled multimedia with explanations which facilitated engagement as students were able to visualize and use auditory cues to comprehend structure and function.

The essence of the observed teaching strategies is that they are different from each other, not only in their approach and style but how they can engage students cognitively (Ruetenik, 2008). For example, student presentations allow students to progress at their own pace, because it enforces independent learning when the student embarks on a journey to find answers about the concept at hand.

Student presenter 2-: So, the order is when it starts with the rRNA, the genes in the fibrillar center which are going to code for transcription along the border of the fibrillar center, now as I have said the fibrillar component surrounds the center and these codes rRNA genes are going to move into the process of pre rRNA around the boundary of the fibrillar center and then when the process begins in the granular component that is where the RNA is assembled with the component making proteins, they move out of the nucleolus and nucleus to the cytoplasm where they develop to be ribosomes which are functioning well ***(Engagement-students presenting cell organelles)***

Student presentations as an eLearning teaching strategy encouraged heightened student participation and teaching by guidance, which was observed in explanations that were narrated by the lecturer after the students finished presenting cell biology concepts, thus this method of teaching promoted engagement which in turn promotes meaning-making (Yu et al., 2022). However, it can be argued that question-and-answer assists students to develop the

capacity to solve situations by combining old schemas into new higher-order schemas (Yu et al., 2022).

Meaning-making can be achieved by the lecturer implementing various teaching strategies in cell biology. One can advocate that there is not one best teaching strategy to teach cell biology that exists on the spectrum, therefore on the pursuit of education and meaning making it becomes of paramount importance that teaching strategies are used interchangeably in the teaching and learning of cell biology.

a) How do the teaching strategies that are used by the lecturer promote the meaning-making of cell biology concepts?

5.1.2 **Finding II:** *The eLearning teaching strategies were used to promote participation and engagement which then promoted meaning-making of cell biology in an eLearning classroom.*

The findings of this study show that the use of various teaching strategies can be used to promote meaning-making in the teaching of cell biology in an eLearning classroom. However, it was observed that different teaching strategies contribute to promoting meaning-making differently. Thus, it becomes central that Life science lecturers are well-informed about different pedagogical practices that can be used to promote meaning-making in an eLearning classroom. To expand on this statement, it is of paramount importance in teaching and learning that a lecturer understands the strengths and limitations of different teaching strategies. For example, student presentations, as observed in this study pose great strength in teaching, they can be used to facilitate learning through collaboration, guidance, and lastly role modelling learning (Martin & Bolliger, 2018). These three features are significant in meaningful learning as they promote participation and active engagement.

The use of student presentations as a teaching strategy resulted in high student participation and control as well as high lecturer participation and control. Concerning the students, they become active agents in their learning which is paramount in meaning-making because it is only when students are actively involved in learning that meaningful learning can occur (Powell & Kalina, 2009).

Lecturer-: Thank you very much (mentions the name of the student, and your team) … that was very detailed and interesting, yes, the nucleolus is found inside the nucleus, and it is the site for protein synthesis - ribosome synthesis. We said ribosomes, are bodies that are built out of ribonucleic acid which means they are derived from strands of ribonucleic acids that are tightly packed of ribonucleic acids. And we just heard the process here… so what processes take place are what was presented to produce ribonucleic acids which is necessary for making ribosomes, but that ribonucleic acid is messenger it's coming out of deoxyribonucleic acid. But that DNA transcribes to RNA, and ribosomal nuclei acid moves out of the nucleus and makes ribosomes….. ***(Engagement- lecturer using the student presentation to explain cellular organelles)***. The lecturer was able to use the presentations to teach certain concepts, and because students had already attempted them on their own, this form of guidance in their learning made it easier for them to comprehend abstract cell biology concepts (see section 4.3.1 D).

Student presentations as a pedagogical practice encouraged participation, not only from the presenters but also from other students. Students asked questions at the end of the presentation which gave the lecturer a platform to address misconceptions and explain the content knowledge of cell biology in a simplified manner (see section 4.3.2). Therefore, student presentations as a pedagogical practice (teaching strategy) promoted engagement which promoted meaning-making.

Learning by collaboration was observed in student presentations since the presentations were done in groups. Group work promotes the sharing of information on a social plane which promotes meaningful learning because when knowledge is shared on a social plane it provides an increase in the expertise of the individual student. Each student shares their perspective with their peers which can be corrected by other scholars. The lecturer was asked during an interview about their reasoning behind the chosen teaching strategy, and the response was narrated as follows "*Students should learn how to engage with resources to develop their understanding, that's one way. And once they have developed that knowledge as individuals, I want them to share that knowledge to learn to share amongst themselves so that they realize that they exist in the ecology of knowledge"*. Therefore, when students engage in presentations, deep cognitive strategies are developed which leads to an improved understanding of the concept thereby promoting meaning-making (Powell & Kalina, 2009).

Therefore, when students are afforded the responsibility to be self-directed learners, they become active participants in their learning (Powell & Kalina, 2009). The concept of promoting meaning-making is deeply engraved in constructivist paradigms, which is according to the social theory postulated by Vygotsky, knowledge is shared on the social plane before it is internalized (see section 2.2). Thus, collaboration and dialogues of question and answers become important in an e-learning classroom because not only do they encourage the sharing of knowledge in the social plane, but they also promote better students, active students, active participation and engagement, and lastly personal interrelationships which are a result of working in a team (Powell & Kalina, 2009).

In addition to gaining knowledge through the sharing of knowledge on a social plane, student presentations also facilitated a question-and-answer session which shows that students are encouraged to participate because their interest in the subject matter is enhanced (see section 4.2.1). The interest of students is enhanced because the inquiry is based on two fundamental things based on the findings:

1. what the students have researched and worked on independently with no assistance from the lecturer,
2. The guidance the lecturer has provided using explanations of the content using 2D and 3D images.

Inquiry-based learning becomes meaningful in an eLearning classroom when it is based on what students can visualize and what they have attempted to do alone without assistance (Powell & Kalina, 2009). Powel and Kalina (2009) denote that meaningful learning is only possible when a student can make the necessary connections and schemas of what they know to what they are being taught. A dialogue of question and answer activates students' prior knowledge which encourages students to engage with the content at hand, it is this kind of engagement that enables students to make connections and schemas of what they already

know with what they are being taught. Therefore, question and answer sessions promote engagement which promotes meaning-making in the teaching and learning of cell biology in an e-learning classroom (see section 2.7).

Question and answer as cited in literature and observed in this study can be used to promote participation which in turn contributes to active learning that is important in meaning-making (see section 2.7). That is, when students are probed during a lesson, they become engaged and that enhances their interest and engagement (see section 2.7). When students are engaged, they participate in the teaching and learning process.

However, in this study an important observation was made that is, a question-and-answer session would work better in a smaller eLearning classroom and that is because every student would be awarded a chance to participate. In this study, the question-and-answer sessions were driven by the same students who were less than 10 and this is out of 200 students that were present in the eLearning classroom. Thus, this observation denotes that, a question-and-answer session in an eLearning classroom is not suitable for engaging all the students thus we cannot be certain that meaning-making is promoted in all the students.

However, it is important to deduce another strength of this teaching strategy. That is the nature of this teaching strategy is essential in an online classroom because it is easy for students to be distracted in the comfort of their homes. Therefore, continuous probing ensures that active learning is taking place and students are not passively listening to the lecturer. The online classroom is accommodative to this teaching strategy such that an option to type an answer in the discussion forum is available, which is an imperative feature since shy students can type their answers in the discussion forum broadening the horizon for participation.

When the lecturer is well equipped with how the different teaching strategies can be used for meaning-making, engagement in the classroom will be enhanced. For example, a lecturer cannot use a question-and-answer session to teach cell structure, but question-and-answer cannot be used to teach how structure relates to function, however, projected 2D and 3D images of the cell as well as videos can be used to teach how cell structure relates to function because students will be able to visualize the different organelles and appreciate how the structures are different from each other.

Also, an attempt to use question and answer when teaching cell structure without any projected visuals might create misconceptions. Therefore, lecturers need to know how to use different teaching strategies appropriately in the classroom so that they can promote meaning-making it was noted in the findings that different teaching strategies stimulate engagement differently thus promoting meaning-making differently. Therefore, if the teaching strategies are used correctly, meaning-making can be promoted.

The lecturer also facilitated explanations of cell biology concepts using projected visuals such as 2D and 3D images as well as videos. Dual coding is a theory that postulates the importance of the incorporation of verbal and visual cues in teaching and learning, that is when teaching a difficult concept like cell structure and function it becomes central that explanations are coupled with visual representations, in that way the comprehension of difficult concepts is promoted (Ngonyani, 2018). That is, students can attach meaning or terminology to what they can see which in turn increases student attentiveness. It is when students are attentive, that

they become engaged which makes it easier for the lecturer to guide them successfully in developing an understanding of difficult concepts. Therefore, explanations that are coupled with visuals encourage engagement which promotes meaning-making.

In this study, it was discovered that the lecturer used an activity where students were tasked to draw a plant cell as a teaching strategy. Literature postulates that the use of drawing activities in teaching and learning makes abstract concepts like cell structure more visible, drawing also enhances and develops critical thinking and comprehension of difficult concepts (Shatri & Buza, 2017). The students not only drew plant cells individually which entails active participation, but they also shared their plant cell drawings on the tutorial pole for everyone to see. The lecturer and other students were both afforded an opportunity to not only see the drawing made by a candidate but also make a comment on the drawing. Therefore, in this manner, the knowledge and skills of biological drawing and cell structure are shared on a social plane which promotes meaning-making.

The written comments narrated by the lecturer provided a basis for guidance. This form of guidance was observed when the lecture asked students questions on what they thought could be improved instead of posting a correct drawing. This method of probing to correct an activity opens a horizon of improvement in the lens of the student, which then encourages experimental learning. Therefore, the student in this process is seen not as a passive recipient of cell biology concepts but as an active participant in the learning process. Engagement in this regard encourages students to acquire a deeper understanding of the structure of the cell, and an appreciation of the different organelle structures and how structure relates to function.

Vavra et al., (2011) postulate that it is only when students are actively engaged that conceptual change can occur. Considering the drawing activity facilitated by the lecturer, one can deduce that it promoted active learning whereby each student was an active participant in the learning process. Therefore, the use of a drawing activity actively engages students which promotes meaning-making in the learning of cell structure and function.

However, considering the advantages posed by this teaching strategy, students in an online classroom may be passive in meeting deadlines and doing tasks with integrity. A handful of drawings were submitted out of the 200 students who are present in the class, which shows that motivation in an online classroom is of paramount importance. Because when students are not encouraged to work on a task, it is observed that they will not. Therefore, tasks that are given to students must contribute to their year mark or a point system must be generated to ensure that students comply. Thus, it is not easy to postulate that activities promote meaningful learning for all students if many of the students are complacent concerning their tasks.

This study showed that 2D and 3D images of the cell can be used to facilitate explanations in an eLearning classroom. The lecturer used 2D and 3D images of the cell as scaffolding or thinking tools in teaching. These visual representations were used to develop a deeper meaning of the content. Meaningful learning was promoted when the lecturer used visual representations to facilitate explanations to encourage deeper meaning of the content, as well as probing which seeks to gain an understanding of what the student knows and understands. Thus, this is a form of learning where new knowledge (new schema) is built upon existing knowledge (old schema). Ignelzi (2002) postulates that this form of learning enhances

comprehension and retention. It is cited in literature that students find it easier to learn and remember knowledge that is communicated visually (Ainsworth, 2008).

In this study, it was revealed that teaching strategies can be used to enhance the interest and motivation of students which in turn promotes engagement and promote meaning-making. The study also showed that the use of diverse teaching strategies is crucial in ensuring that students are active participants in the learning process, thereby increasing their interest and engagement in the learning process. The analysis of the data revealed that students benefit more when different teaching strategies are employed during a lesson as they create interest and engage students.

The study showed how various eLearning teaching strategies help facilitate engagement and participation, that is, it is easier for students to comprehend difficult cell biology concepts when:

- ✔ terminology and concepts are explained in a simplified manner.
- ✔ they can visualize them.
- ✔ they are allowed to present their knowledge.
- ✔ they are asked thought-provoking questions about cell biology concepts.

The use of these teaching strategies that promote participation provided a medium for simplifying concepts that are difficult to conceptualize. Beeland (2002) argues that the interest of students is heightened when they understand what is being taught. The study found that teaching strategies such as facilitating question and answer sessions, multimedia, student presentations, explanations, and a drawing activity are effective in enhancing learning as they enhance engagement. Therefore, the use of teaching strategies that encourage participation in the teaching of cell biology to pre-service teachers enhances engagement thus promoting meaning-making in an eLearning classroom.

Teaching strategies employed in this study by the lecturer promoted greater participation, engagement, and meaningful learning in students. This study shows that when a lesson encourages student engagement, by using teaching strategies such as multimedia, student presentations, question and answer sessions, and facilitating drawing activities students become stimulated thus promoting better involvement with cell biology concepts and hence leading to meaningful learning in an eLearning classroom.

5.2 Recommendations for the study

This study showed that teaching strategies can be effectively used to engage and promote meaning-making. The study, therefore, recommends that …

- Lecturers and pre-service teachers are taught how to effectively use various teaching strategies for specific Life Sciences topics because every topic is different and requires a different approach, therefore the use of the same method across all topics will not only hinder the promotion of meaning-making but also it might create disengaged students as it might instill the notion that Life sciences are difficult to comprehend.
- This study was limited to only one topic and that is cell biology and one individual lecture and how he used different teaching strategies to teach cell biology in an

eLearning classroom. More research needs to be done to investigate how various lecturers use different teaching strategies to teach other topics within and outside the discipline of biology, and how effective are those teaching strategies in promoting meaning-making.

5.3 Conclusion

This study aimed to investigate how the lecturer promotes meaning-making when teaching cell biology to 1st-year Natural science pre-service teachers in an eLearning classroom. The study managed to investigate how meaning-making was promoted using various teaching strategies employed by the lecturer in the teaching and learning of cell biology in an eLearning classroom. Various teaching strategies were employed by the lecturer in the teaching of cell biology. The study found that the use of various teaching strategies such as question-and-answer teaching strategy, explanations, multimedia (i.e., the use of projected 2D and 3D images), student presentations and lastly drawing activities stimulated engagement which in turn promoted meaning-making in the teaching and learning of cell biology in an eLearning classroom. The lecturer used the teaching strategies interchangeably to promote engagement which promotes meaning-making. The findings of this study indicate that the use of various teaching strategies interchangeably in the teaching of cell biology promoted meaning-making to first-year Natural science pre-service teachers in an eLearning classroom. The study therefore recommends that for meaning-making to be promoted in the teaching and learning of cell biology concepts; various teaching strategies must be employed in the eLearning classroom when teaching cell biology. The teaching strategies, however, must be used interchangeably to support knowledge construction.

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APPENDIX ONE

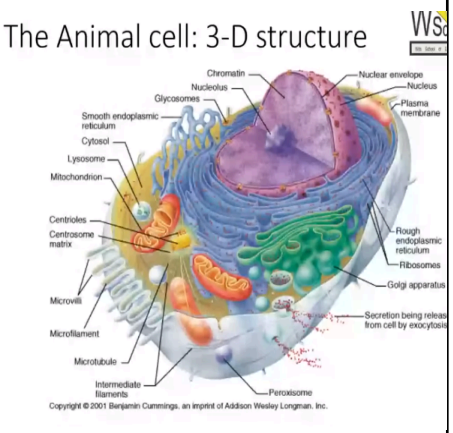
Table 1 shows how data was analyzed from the video recordings obtained from the BBB (BigBlueButton).

Pedagogical knowledge *(Type of eLearning teaching strategy used by the lecturer)*	**Content knowledge** *(Concept being taught)*	**Technological knowledge** *(The BigBlueButton was used as an online classroom and the lecturer used his laptop to facilitate teaching. It is worth noting that the BigBlueButton can be accessed using electronic devices such as a cellphone, tablet, and laptop)*	How was the teaching strategy used?
1. ***Question-and-answer teaching strategy*** using synchronous communication which includes the chat room, webcam, and audio which are initiated by virtually the raising of hands on the BigBlueButton.	1. Cellular organelles (i.e. Ribosomes, lysosomes, peroxisomes). 2. Cellular organelles (i.e Endoplasmic reticulum)	1. The lecturer used screenshare on the BigBlueButton to project a 3D image of an animal cell to facilitate an explanation of the structure and function of cellular organelles ***(eLearning teaching strategy- Lecturer using the webcam video and screen sharing on the BigBlueButton to facilitate the question and answer teaching strategy)*** 2. Students virtually raise their hands on the blue button conference and the lecturer recognizes the student's hands by verbalizing the student's name via the webcam video on the BigBlueButton ***(eLearning teaching strategy- Lecturer using the webcam video and screen sharing on the BigBlueButton to facilitate the question and answer teaching strategy)*** 3. Students respond synchronously in two ways either by writing their answers in the chat room or	-The student asked the lecturer through the audio feature on the BigBlueButton if the ribosomes are the same organelle as the peroxisomes, and lysosomes ***(Engagement-meaning making-student asking the lecturer a question via the audio feature on the BigBlueButton)*** -The lecturer answered the student through the webcam on the BigBlueButton and explained the biology terminology by explaining how each word was constructed to bring about meaning ***(Engagement-meaning making- Explanation of the content using the webcam video on the BigBlueButton)*** *Student virtually raises their hand* ***(Participation- meaning making-student virtually raising their hand on the BigBlueButton)*** *Lecturer-: Calls the student's name through the webcam on the BigBlueButton* ***(Engagement-meaning making-Lecturer calling the student by name using the webcam video on the BigBlueButton)*** *Student-: Sir, is a peroxisome and lysosome a type of ribosome? Or are*

		by verbalizing their responses through the audio platform ***(eLearning teaching strategy- Lecturer using the webcam video and screen sharing on the BigBlueButton to facilitate the question and answer teaching strategy)***	*they different from ribosomes?* ***(Engagement- meaning making-student asking the lecturer a question via the audio feature on the BigBlueButton)*** *Lecturer-: those are different organelles. There is something called "some", there is that "some" thing at the end of that common term, some. Some are coming from a term called soma which means body, so those are three different bodies, and the first part you'll find that biological terms, most biological terms are described by a combination of terms so peroxi is one word and some are another word. So, peroxisomes are structures that are built from peroxi and there is a word called somebody. If you hear the word "peroxi", what does it relate to? A substance? **(Engagement-meaning making-Explanation of the content using the webcam video on the BigBlueButton)*** *Student virtually raises their hand* ***(Participation- meaning making-student raising their hand on the BigBlueButton)*** *Student-: peroxide.* ***(Participation-meaning making-student answering the lecturer's question via the audio feature on the BigBlueButton)*** -The lecturer posed a question to the students regarding the endoplasmic reticulum through the webcam on the BigBlueButton (***Engagement- meaning making-lecturer asking students a question using the webcam video on the BigBlueButton***). The students answered the questions the lecturer through the audio feature on the BigBlueButton conference by virtually raising their hands, and others posted their answers on the chat platform on the BigBlueButton ***(Participation-meaning making-student answering the lecturer's***

			question via the audio feature on the BigBlueButton) -As the students answered the questions, the lecturer posed simplified and easier follow-up questions via the webcam on the BigBlueButton. Which resulted in a synchronous discussion on the chat platform and via the audio feature. *Lecturer-: what is the opposite of endo?* ***(Engagement-meaning making-Lecturer asking students a question via the webcam on the BigBlueButton)*** *Student-: it's Exo* ***(Participation -meaning making-student answering the lecturer's question via the audio feature on the BigBlueButton)*** *Lecturer-: exactly, so you find a structure called the endoplasmic reticulum. The smooth endoplasmic reticulum is made of four different words then the other one is plasmid* ***(Engagement- meaning making-explanation of the content via the webcam on the BigBlueButton)***. *What does plasmid refer to?* ***(Engagement- meaning making-lecturer asking the students a question via the webcam on the BigBlueButton)*** *Student virtually raises their hand* ***(Participation- meaning making-student virtually raising their hand on the BigBlueButton)*** *Student-: small net* ***(Participation-meaning making - student answering the lecturer's question via the audio feature on the BigBlueButton)*** *Lecturer-: the small net is the reticulum. The reticulum is a small net* ***(Engagement- meaning making-lecturer asking the students a question via the webcam on the BigBlueButton)*** *Student virtually raises their hand* ***(Participation-meaning making-***

			student virtually raising their hand on the BigBlueButton) *Student-: Sir, I think Plasmid means membrane* ***(Participation- meaning making - student answering the lecturer's question on the audio feature on the BigBlueButton)*** *Student-: sir connected with* ***(Participation- meaning making - student answering the lecturer's question on the audio feature on the BigBlueButton)*** *Student-: something with plastic* ***(Participation- meaning making - student answering the lecturer's question on the audio feature on the BigBlueButton)*** *Lecturer-: not plastic. Endoplasmic reticulum. Endo – inside the plasma. Inside.* ***(Engagement- meaning making-explanation of the content via the webcam on the BigBlueButton)*** *Student virtually raises their hand* ***(Participation-meaning making- student virtually raising their hand on the BigBlueButton)*** *Student-: plasmid means the membrane* ***(Participation- meaning making - student answering the lecturer's question via the audio feature on the BigBlueButton)***
2. Explanation using webcam video and screen share	Cell structure and function	-The lecturer used screenshare on the BigBlueButton to project a 2D and 3D image of an animal cell and a video ***(eLearning teaching strategy- Lecturer uses webcam and screenshare on the BigBlueButton to facilitate an explanation)***	- The lecturer used screenshare on the BigBlueButton to project a 2D labeled diagram of an animal cell to explain the structure of an animal cell, then used a 3D image to explain what students are going to see when using an electron microscope as opposed to when they are using a light microscope ***(Engagement-meaning making-Explanation of the content using a projected image via the webcam on the BigBlueButton).***

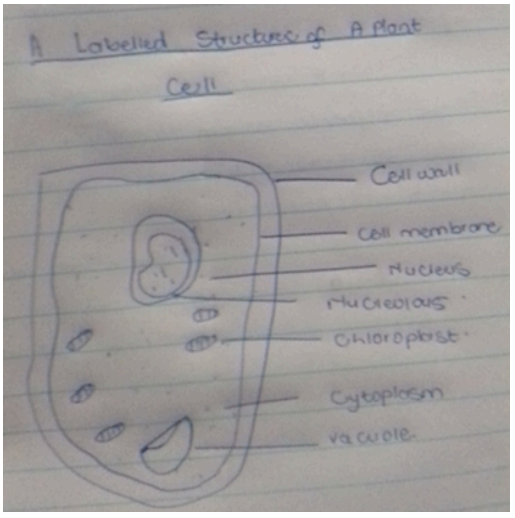
		-Lecturer uses a question posed on the chat platform on the BigBlueButton forum to explain terminology ***(eLearning teaching strategy- Lecturer uses webcam on the BigBlueButton to facilitate an explanation)***	*{shows a slide that has a labeled 2D colored picture of an animal cell}* *Lecturer-: Today we are talking about the Animal cell, if you are looking at a light microscope you are likely to see a cell membrane, mitochondria, cytoplasm, nucleus, chromosomes, glycogen granule, and small vacuole but that depends on the power of the light microscope. Most of the light microscopes that we use do not enable you to see a mitochondrion inside the cytoplasm. You'll be able to see the cell membrane, nucleus, and some spots inside the nucleus which constitute the nucleolus and some vacuoles so this one is an elaborate animal cell. You won't be able to see this much in the light microscope that we use, I'll make you do that when we open it. You are going to have a practical activity of looking at your cheek cells as well as some plant cells using the microscope* ***(Engagement-meaning making-Explanation of the content using a projected image via the webcam on the BigBlueButton)*** {shows a labeled 3D image of an animal cell}  *Lecturer-: Right when you use an electron microscope you are going to see a deeper version of that cell. This one is a typical animal cell because it has all the features that you find across*

			animal cells. If you look at some animal cells, they may not have these features. Blood cells for example may not have those structures. They may just have a cell membrane and hemoglobin inside. White blood cells may not have microvilli, and most cells may not have microvilli, but someone gave an example of cells in the alimentary canal, where absorption takes place. Some of those cells have their protrusions which increase the Surface area for absorption so they will have a microvillus ***(Engagement- meaning making-Explanation of the content using a projected image via the webcam on the BigBlueButton).*** *So, one could find a flagellum somewhere, add on this one. Not all cells have a flagellum, can anyone think of an animal cell that has a flagellum?* ***(Engagement-meaning making-lecturer asking students a question via the webcam on the BigBlueButton)*** *Student virtually raises their hand* ***(Participation-meaning making-student raising their hand on the BigBlueButton)*** *Student: It's a sperm cell* ***(Participation-meaning making-student answering the lecturer's question via the audio feature on the BigBlueButton)*** *Lecturer-: thank you. Thank you very much for that contribution, a sperm cell is one of the cells that have a flagellum* ***(Engagement-meaning making-lecturer communicating to validate the student's response via the webcam on the BigBlueButton)*** *[A student posted a question on the chat feature; "what is the difference between Mitochondrion and Mitochondria?"]* ***(Participation- meaning making-student asking the lecturer a question on the chat platform on the BigBlueButton)***

			*Lecturer-: Anyone to help (mentions the name of the student). What is the difference between mitochondrion and mitochondria? **(Engagement -Lecturer asking students a question via the webcam on the BigBlueButton)*** *Student raises their hand **(Participation-meaning making-student raising their hand on the BigBlueButton)*** *Student-: greetings. Okay mitochondrion is singular, and mitochondria is plural **(Participation-meaning making-student answering the question posed by the lecturer via the audio platform on the BigBlueButton)*** *Lecturer-: thank you very much that is correct when you are talking about one it's mitochondrion and when there are many it's mitochondria. Thank you, this is what you find in an animal cell if you look at it with the electron microscope, you can see this because it has a high resolution, or has a high resolving ability or high-resolution power. You can see the nucleus and nucleolus; you can see the smooth ER. So, you will find mitochondrion you will find lysosomes, centrioles you'll also see microvilli, microtubules, intermediate filaments, peroxisomes, exocytosis vesicles, and the endoplasmic reticulum and the ribosomes that we talked about under prokaryotes. In this, we are going to have two types of ribosomes one of them is those that are attached to the ER, so they are ER-bound and the other one is free ribosomes in the cytoplasm. And of course, all of these are enclosed within the plasm membrane or plasmalemma. So that is what you will find in a typical animal cell, typical because all the features of the animal cells have been brought into one. It is not a muscle cell or nerve cell; it is a typical animal cell*

			that is brought by all the features ***(Engagement- meaning making-Explanation of the content using a projected image via the webcam on the BigBlueButton)***
3. Class activities using the whiteboard on the BigBlueButton and Tutorials on the BigBlueButton	The structure and function of a cell.	-The lecturer posed a question on the whiteboard via the BigBlueButton after using a PowerPoint presentation to explain cell structure and function ***(eLearning teaching strategy- Lecturer uses the whiteboard on the BigBlueButton to facilitate the class activities)*** - The lecturer facilitated a tutorial where students were asked to draw a plant cell and post their drawings on the tutorial pole ***(eLearning teaching strategy- Lecturer uses the tutorial platform on the BigBlueButton to facilitate a tutorial session)***	-The lecturer taught the structure and function of the cell via the webcam on the BigBlueButton, then gave students a task to think about what they would like their students to know when they teach cell structure and function on the whiteboard via the BigBlueButton **(Engagement- meaning making-Lecture facilitating an activity on the BigBlueButton).** -Students then responded verbally via the audio platform on the BigBlueButton wrote their answers to the chat forum via the BigBlueButton, and explained what they would like their learners to know **(Participation-meaning making-student answering the question via the audio and chat platform on the BigBlueButton)** -The lecturer then asked follow-up questions to students via the webcam on the BigBlueButton ***(Engagement-meaning making-lecturer asking students questions via webcam on the BigBlueButton)*** *Lecturer-: Having seen the structure of an animal cell, what would you want your learners to know about an animal cell? I'll give you 30 seconds to think about it and you respond. What would you like your learners to know?* ***(Engagement- meaning making-Lecture facilitating an activity on the BigBlueButton)*** *Student raises their hand* ***(Participation-meaning making-student raising their hand on the BigBlueButton)***

			Student-: I would like my children to know that an animal cell has membrane-bound organelles which are called lysosomes, these membrane-bound organelles are found in animal cells and contain a hydrologic enzyme that digests waste products of the cell, this lysosome has a lysosomal membrane which keeps the enzymes contained last things digestive cell cause autolysis. The rough endoplasmic reticulum, sir I think I'm done ***(Participation-meaning making-student answering the question via the audio platform on the BigBlueButton)*** *Lecturer-: and why would you want them to know that?* ***(Engagement – meaning making-lecturer asking a follow-up question via the webcam on the BigBlueButton)*** *Student raises their hand* ***(Participation-meaning making-student raising their hand on the BigBlueButton)*** *Student-: I would like them to know this because the Lysosome is a lot of the distraction of the animal cells so if there is no lysosome there are not a lot of distractions* ***(Participation-meaning making- student answering the question via the audio platform on the BigBlueButton).*** -The lecturer facilitated a tutorial where students were asked to draw a plant cell and post their drawings on the tutorial pole ***(Engagement- meaning making-lecturer giving students a task via the tutorial pole on the BigBlueButton)*** -Students responded by drawing the plant cell and then posting their drawings on the tutorial pole ***(Participation – meaning making -students responded by drawing the plant cell on the tutorial pole via the BigBlueButton)***

			-The lecturer then posed questions to the students guiding them regarding their drawings ***(Engagement- meaning the making-lecturer guiding students on how to improve their drawing via the webcam on the BigBlueButton)***, and other students commented on each other's drawings ***(Participation-meaning making-students responding to drawings on the tutorial pole)*.** *Lecturer-: I would like you to post pictures of your plant cell drawings and make comments on those from your colleagues. This is just a practice activity and is not assessed* ***(Engagement –meaning making-lecturer giving students a task via the webcam on the BigBlueButton)*** *Student 01-: Here's my plant cell* ***(Participation -meaning making-student post a drawing of the plant cell on the tutorial pole via the BigBlueButton)***  *Lecturer-: Thank you. Reflecting on the lesson yesterday on the cow, what was done well, and what could be improved on this diagram?* ***(Engagement-meaning making-lecturer guiding students on how to improve their drawing via the webcam on the BigBlueButton)***

4. Group work facilitated through presentations via the audio platform and screenshare	Cellular organelles (i.e., Chloroplast and the centrioles).	Students worked as a group to discuss and share ideas on cellular organelles and then presented their combined knowledge using PowerPoint presentations via the audio platform and screenshare on the BigBlueButton ***(eLearning teaching strategy- Lecturer facilitated group work using student presentations via screenshare and audio on the BigBlueButton)***	-The students presented cellular organelle structure and function ***(Participation-meaning making-students presenting cell organelles via screenshare and audio on the BigBlueButton)*** and the lecturer used their presentations to guide the students on what they should know regarding the presented organelle and how to teach and construct the lesson ***(Engagement-meaning making-lecturer used the student presentation to explain cellular organelles via the webcam on the BigBlueButton)*** The presentations were done in groups ***(Participation-meaning making-students presenting cell organelles via screenshare and audio on the BigBlueButton)*** --- ***Student projects PowerPoint presentation via screenshare on the BigBlueButton*** *Student presenter 3-: Good morning to my fellow students. I'm the presenter for my group. These are the names of my group members. First, I would like to take you through the content of our definition, region, structure, functions, and diagrams and share recommendations where you can get more information about the centriole. First, we are going to talk about the definition of a centriole, I have a diagram with me whereby you can see the structure, and another structure here is the animal cell. Centrioles are two cylindric, rod-shaped microtubular structures, near the nucleus. They are not present in the prokaryotes, red algae, yeast, cone-bearing, and high flower plants, and*

			also, non-flagellated or ciliated protozoans (such as amoebae). Centrioles form a spindle of microtubules, the mitotic apparatus during mitosis or meiosis, and sometimes get arranged just beneath the plasma membrane to form and bear flagella or cilia in flagellated or ciliated cells. Thank you, next slide, ***(Participation-meaning making- students presenting cell organelles via screenshare and audio on the BigBlueButton)*** *(Projects 2D labeled drawings of centrioles)* *Lecturer-: thank you very much, sorry you could not present from that side I also had a challenge here. What is interesting is that this is an animal cell organelle, it is only found in animal cells. You must take note of that because we are going to ask you where these organelles are found and where they are not found* ***(Engagement-meaning making- lecturer tells students to take notes via the webcam on the BigBlueButton)*** *Student raises their hand* ***(Participation-meaning making- student virtually raising their hand on the BigBlueButton)*** *Student presenter 3-: okay sir, on that on which these organelles are not found I think I've mentioned in the origin where I said they are not found in the prokaryotes, algae, and other high plants. They are not present there; I don't know if anyone is having a challenge in understanding that* ***(Participation-meaning making- student elaborates on what the lecturer has stated on the audio platform via the BigBlueButton)*** *Lecturer-: Yes, thank you. that's what I'm emphasizing when we are going to*

			ask you questions in exams, we are going to ask you where they are found and where they are not found, and we may ask you about the structure and function as well.: so, centrioles ***(Engagement-meaning making-lecturer using student presentation to explain cellular organelles via the webcam on the BigBlueButton)*** *(Lecturer projects a 3D image of centrioles)* *I'm projecting this image because it's speaking to a structure, I want you to know and understand* ***(Engagement-meaning making-lecturer using student presentation to explain cellular organelles via the webcam on the BigBlueButton)****. The centrioles exist in pairs, and their units are always at right angles to each other all the time there are two centrioles, they are sitting at right angles to each other. Please don't ask me why I don't know why but this is how they are always. It's not like this diagram has been made for two different centrioles but this structure you are seeing here is describing one set of centrioles. Every time you indicate a centriole in a cell you are referring to a pair, two of them when they are together and these two for each one of them, have nine triplets of microtubules there are three that form a triplet and there will be nine of them on the outside. And inside there, there is a pair there are two triplets where you put that tube. They show nine-plus two arrangements of microtubules, the nine describe the ones on the outside. nine triplets of microtubules on the outside, and then the two describe the two sets of triplets that are found inside so centrioles display a 9+2 arrangement of microtubules. That is one part that is not added there. These microtubules are built out of a protein called tubulin, so tubulin units are used to build microtubules and each of those tubules*

			is associated with two others to form triplets as given centrioles are 0.25 micrometers in diameter and are 0.3 micrometers, 2.7 micrometers in length. So, they vary in length and diameter depending on the animal species and the cells and a few could be having the diameters I've mentioned elsewhere. Centrioles are associated with microtubules and microfibres around them, and that structure is called a centrosome. Microtubules are found within a centrosome, some of you will end up asking what the relationship between a centrosome and centrioles is. Centrioles are found within a set /collection of microtubules, there will be microtubules around there. And that whole structure which has microtubules inside it and microtubules around it is around a centrosome. And that "soma" is a body again, Thank you. ***(Engagement- meaning making-lecturer using student presentation to explain cellular organelles via the webcam on the BigBlueButton)*** *Student presenter 3- Sir thank you I'm very glad that you highlighted the differences. Between centrioles and centrosomes* ***(Participation -meaning making- student responding to lecturer's explanation on the audio platform via the BigBlueButton)***
5. Video-based learning via screen sharing on the BigBlueButton	The structure of a prokaryotic cell	The lecturer showed students a video of a prokaryotic cell via the screen-sharing platform on the BigBlueButton ***(eLearning teaching strategy- Lecturer using a video to facilitate an explanation of prokaryotic cells)***	The lecturer plays a video on prokaryotic cells to help learners visualize prokaryotic cells ***(eLearning teaching strategy- Lecturer using a video to facilitate an explanation of prokaryotic cells)*** *[Lecturer plays a video on prokaryotic cells]* *Student raises their hand* ***(Participation-meaning making- student virtually raising their hand on the BigBlueButton)***

			Student-: Sir, I would like to know what he meant when he said that the cell wall and cell membrane contain something what do they contain ***(Participation-meaning making- student asks a question regarding the video that was played on the audio platform via the BigBlueButton)*** *Lecturer-: I don't know. Is there anyone to help with the difference between a cell wall and a cell membrane?* ***(Engagement- meaning the making-lecturer asking students a question via the webcam on the BigBlueButton)*** *Student-: No sir, I am not asking that he said the cell wall and cell membrane contain saccharides I think something. I remember learning that the cell wall contains cellulose, and the cell membrane contains proteins, so I wanted to get clarity on that.* ***(Participation- meaning making- student asks a question regarding the video that was played via the audio platform on the BigBlueButton)*** *Lecturer-: I think he said saccharides.* ***(Engagement- meaning making-lecturer answering a student question via the webcam on the BigBlueButton)*** *Student-: Yes* *Lecturer-: Anyone who knows what saccharides are* ***(Engagement-meaning making-lecturer asking students a question via the webcam on the BigBlueButton)*** *Student raises their hand* ***(Participation-meaning making-student raising their hand on the BigBlueButton)*** *Student-: Saccharides are sugars, Sir.* ***(Participation- meaning***

			making-student answer the question posed by the lecturer via the audio platform on the BigBlueButton) *Lecturer-: Sugars so? **(Engagement -meaning making-lecturer poses a question to the students via the webcam on the BigBlueButton)*** *Student raises their hand **(Participation-meaning making-student raising their hand on the BigBlueButton)*** *Student-: Saccharides are sugars found in the cell wall **(Participation- meaning making-student answer the question posed by the lecturer via the audio platform on the BigBlueButton)*** *Lecturer-: Saccharides are sugars. Cell walls are mainly made of polymers of sugars and other substances such as murine. We'll get there, what we were talking about…. When we talk about the differences between cells, we are highlighting the differences between living things. When we are identifying organisms as prokaryotic, we are grouping them into two large groups. One group is prokaryotic organisms then another huge group is eukaryotic **(Engagement-meaning making-Explanation of the content via the webcam on the BigBlueButton)*** *(The lecturer plays a video of someone drawing the eukaryotic cell) **(eLearning teaching strategy- Lecturer playing a video)*** *Lecturer-: Okay, I would like for you to critique that video. what was done well and what was not done well, I don't want the answers now, but it is something to think about as you go through this course. What is it that you are going to do yourself and what is it that you won't do, looking at the initial*

			presentation we had on the first day about making diagrams, what would you take and what would you not take and what would you do better on you own ***(Engagement-meaning making-lecturer giving students a task based on the video via the webcam on the BigBlueButton)***

APPENDIX TWO

Video transcript

Lesson: Introduction to the cell

[Projected a 2D and 3D images of shapes]

Lecturer-: Just to illustrate the effort of increase in size on the relationship between surface area to volume ratio. We are trying to illustrate that as the size of the organelle, the size of the cell increases it exposes less surface area for its contents. And that surface area is necessary for the exchange of materials. These may be in the form of food and, the removal of waste products of metabolism. Food is necessary for metabolism but excretion is for removal of waste products of metabolism so a bigger surface area will allow the content of that organism to exchange comfortably but when the surface area becomes smaller the organelle is not able to exchange the materials as much and as fast as they are needed or as fast as they are supposed to be removed out, so in order to calculate surface area to volume ratio of that structure and then its volume then you bring these into a relationship surface area and volume ratio and we realize that when we have a dimension to one unit you have a surface area of 6:1 when you have a surface area of two units it comes down to 3:1 that means there is less surface area in relation to the volume of that organism and it follows that its volume increases so that the need for nutrients and production of waste as size increases that is very important number four as size increases volume, increases faster that the surface area therefore that increases in volume creates a bigger demand on the surface area. Therefore, the volume must remain small and that is why cells are small. Cells are tiny, not because they have to be packed into a big organism, we would not have elephants having those billions of cells probably God would just make a few big ones. But because those cells have requirements that need them to be small. All organisms on Earth consist of many small cells then the cells can increase in number and that helps the organisms to live comfortably. That is where we ended last time, I usually give two questions on that section but today we are starting on what a cell is. I would like to hear from you. What is a cell? I have already shown you. What is a cell?

Silence…

Lecturer-: Anyone who can come in? Excuse me I cannot see, let me go back… (*calls the name of the student).*

Students raise their hands…

Student-: Meneer, from what I have read so far, they say a cell is a basic unit of life.

Lecturer-: Okay, it is a basic unit but what is it? (*Calls the name of another student*).

Student -: Hello Sir and everyone so the cell is the basic unit of life which means for an organism to live it should have a cell, it is the one that provides a I can say many things for us to live such as protein and all that.

Lecturer-: *Calls another student's name*

Student -: Hello Sir,

Lecturer-: *Calls another student's name*. What is a cell?

Student-: Hi, okay… so far, I think a cell is a basic unit of life where the vital processes in the body occur such as metabolism as you mentioned earlier.

Lecturer-: Okay, thank you. *Calls another student's name*. Your hand is up

Student-: Greetings… I think that a cell is a building block of all living things.

Lecturer-: Thank you. What do you mean by that?

Student-: I mean that living things have cells like cells are monomers of living things. We are created of cells.

Lecturer-: Thank you. *Calls another student's name.* What is a cell? Your hand is up.

Student-: Is the smallest unit that can live on its own and it makes up living organisms and tissues in the body.

Lecturer-: What is a cell?

Student-: Sir I will say what I learned in high school. A cell is the smallest structure or functional unit in organisms, it is microscopic, and in order when it comes to organisms it is first the cell then the tissues, it is the organs. The cells are the basic units of organisms.

Lecturer-: Okay. The next one (*calls another student's name*)

Student-: Yes Sir, so the cell is the smallest basic unit of life that is responsible for all life's processes.

Lecturer-: Thank you.

Student-: Greetings, A cell is the smallest unit made up of cell membrane, nucleus, and DNA.

Lecturer-: *Calls a student name…*

Student-: Sir I think a cell is a basic unit of life meaning that it is responsible for providing all functions for living things.

Lecturer-: Thank you (*calls a student's name*).

Student-: Good day Sir, I think a cell is a basic unit of life that is responsible for all living things.

Lecturer-: All the contributions you have made are correct however I want to focus on this definition, that it is a highly organized compartment, it is a compartment which is in some cells in the form of a box. It is a form of a box because it is made of hard, tough material but the tough material is on the outside it surrounds a thin flexible membrane. So, a cell is a structure that is surrounded by a thin flexible membrane which is the plasma membrane or cell membrane. Some want to call it the plasmalemma and that contains concentrated chemicals in an aqueous solution called the cytoplasm. That is the simplest of definitions. It is a highly organized compartment. That is very important, that organization part is what you need to be asking yourself. What makes it highly organized? It is not chaotic, it is highly organized, the opposite of organization is chaos. It is not chaotic inside there. It is highly organized, and you have mentioned that it is a unit that can stand on its own, it is a compartment that thin flexible membrane compartmentalizes the cell. It makes the cell a compartment, however, some cells have a cell wall outside them, and we still call them cells. We are still going to talk about some cells with and some cells without a cell wall which is a fixed compartment but inside that fixed compartment there will be a thin and flexible membrane and that membrane is a cell membrane. The cell membrane contains a highly organized set of structures which we'll call organelles. And those organelles are not just sitting there, they are not sitting in dry air like you are they are sitting in a fluid and an aqueous solution. They are sitting in an aqueous solution that contains concentrated chemicals and I have put in brackets there, the term aqueous implies watery. It is a solution of substances in water. So that mix of suspended substances and materials and chemicals in a solution of water is what we call the cytoplasm when you look at a typical cell, we always draw a cell as having a cell membrane, cytoplasm, and nucleus. If you remember your grade 4, 5,6, and probably grade 9 drawings of the cell, they only had the cell membrane, nucleus, and cytoplasm but we are going on to say that the cytoplasm is highly organized and the thin flexible membrane on the outside the cell membrane compartmentalizes the cell. It makes it a compartment and all the contents of the cell are found within a fluid in a liquid and that liquid is mainly water, and water has substances dissolved in it so it is a solution. And what substances are dissolved in it, we have substances that are taken into the cell and some of those substances are what we eat. Next to me is a cup of water which is going into my body, that water is not just going into my alimentary canal, it is going into my blood. It will end up in my tissue fluid surrounding cells, some of it passes by osmosis into my cells, and into those cells, it constitutes the basis of the cytoplasm. So when you feel thirsty, not for beer because it's Friday. When you feel thirsty for water, your body is telling you that there is less water flowing in your blood which means that there is less water available for your tissue fluid and there is less water available for your tissue fluid and there is less water available for your cells and there is less water available for your cells and there is less water available for your cytoplasm (aqueous solution). So that is the starting point, this is the basic. Then we are going to look at the organization of the structures inside the cell, we are going to look at the cell membrane itself, what makes it unique, why am I mentioning it here and we might even talk about some of the substances that move in and out of the cell those that are dissolved in the cytoplasm and can move in and out we may talk about them now or in the future but mainly the organization of the cytoplasm and cell content. We are going to be focusing on issues of structure and function and how the structure is related to function. You have told me

equivocally that all organisms consist of at least one cell, and that the cell is the basic unit of life. Why? It is the smallest unit that shows characteristics of life. That is the first thing of the cell theory. All organisms consist of one or more made from existing cells. I gave an example of me being made of billions of cells; some are being made some are dying. For those cells to be made, my mother contributed a cell with half the number of chromosomes, my father contributed a cell with half the number of chromosomes they fused through the process called fertilization. When that zygote was formed it formed the beginning of a new life. That very first cell just grew into a huge me, it multiplied through the process called mitosis, into a huge lump of cells which became an embryo, and that embryo had cells which became an embryo and that embryo had cells specializing into different parts of my body. Some became muscles, some became the head, some became the bones, some became nails and some became blood, etc, they became tissues and organs. You mentioned that the cells are responsible for that, one cell resulting in all these other cells that have the same genetic makeup. They are made from existing cells, all these body cells I am proud of arose from one zygotic cell. Cells are made from existing cells. Please come in with that question again.

Student-: Sir, is an acellular organism considered non-living?

Lecturer-: Can you give an example of an acellular organism?

Student-: To be honest I haven't heard of any sir.

Lecturer-: Anyone who can help with an acellular organism?

Student-: A sponge is one.

Lecturer-: Is sponge acellular? I think a sponge is a…. Are you saying the sponge in an ocean?

Student-: Acellular, I think they include fungi and viruses and algae.

Lecturer-: What do they include?

Student-: Sir, I am not sure, but I think it's viruses, fungi, and algae. They have a single cell or acellular.

Student-: Correct but including bacteria and earthworms.

Lecturer-: What is acellular meaning?

Student-: Hello Sir,

Lecturer-: Yes

Student-: Acellular are organisms that don't contain any cells and bacteria isn't an acellular organism because it contains only one cell which is acellular.

Lecturer-: Thank you very much. That word organism, when you are talking about organisms, organisms are supposed to have life. If you find a resource that talks about acellular organisms, then it is not proper. An organism is supposed to have life, we can talk about unicellular and multicellular organisms. If it is acellular there should be another term after it that describes that structure. Acellular structure refers to the absence of cellularity. Absence of features of a cell so it is not an organism because….

Student-: So, sir can I contribute sir?

Lecturer-: Yes

Student-: It means that a virus is acellular something because I can't say organism.

Lecturer-: Perfect. Viruses are acellular.

Student-: Sir aren't viruses organisms that multiply, even if they don't multiply by themselves they multiply while feeding on something so I think they can be called acellular microorganisms.

Lecturer-: Viruses are microscopic structures, but they are not organisms. How do viruses multiply? They cannot multiply on their own… Your cells can reproduce by mitosis but if you want to mix yourself, viruses cannot mix themselves they go into the host cell to multiply. That is why viruses cannot reproduce they are only two features that may link viruses to characteristics of life. That one of reproduction. Many people want to say viruses reproduce, but they don't. The other one is sensitivity; I mentioned this last time that viruses are sensitive because of the proteins on them. Recognition proteins recognize the host so they can attack a particular host. These are the two features that could cause one to argue that viruses are living but they aren't, they are acellular in nature. So, there are two types of cells and two major groupings. The first type is prokaryotic which includes bacteria, archaea, and blue-green algae. When we talk about biodiversity, we are going to talk alloy about bacteria and blue-green algae. Blue green algae are usually the algae you see if you haven't cleaned a swimming pool or if you go to a pond of water especially the polluted rivers that receive raw sewage you find the water is green it is the blue green algae. They do not contain membrane-bound organelles including the nucleus they do not have a nucleus. Mostly single celled but you do have some that are multicellular. Then you have others that are eukaryotic, and these are plants, animals, and Protista. They contain membrane-bound organelles inside their cell membranes. And there will be a nucleus this was that some are single-celled, and some are multicellular. Yes, someone wants to talk… (*calls a student's name*)

Student-: Sir if prokaryotic cells do not contain a nucleus where is the DNA?

Lecturer-: We will see that just now. Their DNA is in the cytoplasm (*calls another student's name)*

Student-: Sir you see these prokaryotic cells, do not contain membranes and a nucleus, right? So, sir can we say are those cells?

Lecturer-: They are cells except that they are prokaryotic cells

Student-: Prokar…. Thank you, Sir.

Lecturer-: They are P-R-O-K-A-R-Y-O-T-I-C. Train yourself. (*Calls another student's name*)

Student-: How do bacteria reproduce themselves?

Lecturer-: We'll talk about it during biodiversity lessons. We'll talk about binary fission which is asexual and conjugation which is sexual.

Student-: I want to ask about the membrane-bound organelles. Can we say the membrane of a prokaryotic cell is not developed like a eukaryotic because if we say they do not contain

membranes that means the organelles will be floating in the body. I don't know if it makes sense, they won't be contained in one area. What I'm asking is can we say the membrane-bound organelles of a prokaryotic are not developed but there is a membrane?

Student-: Can I contribute?

Lecturer-: Yes, contribute.

Student-: Sir, I think when they say membrane-bound organelle, they do not mean they don't have a cell membrane it just means they mean they do not have things like rough endoplasmic reticulum, things like that.

Lecturer-: Thank you very much for that. It is very correct they do not have a cell membrane but do not have those internally membrane-bound structures. Thank you.

Student-: I have a question Sir; I understand this topic but what I do not get is if we were asked to define prokaryotic cells. How would you define it? Would you say that prokaryotic cells are cells that do not contain membrane-bound organelles, is there a specific definition for this?

Lecturer-: Can I leave the class to try and answer his question?

Student-: Okay, to answer you I would define a prokaryotic as a single that doesn't contain the nucleus and other membrane-bound organelles.

Student-: So, you are putting it in your own words?

Student-: Yes, from what was explained that is what I am putting together.

Student-: No most of them are single-celled and not all of them.

Student-: You cannot be specific and say they are unicellular while some bacteria are multicellular.

Student-: I think prokaryotic are organisms whose genetic material is not surrounded by a nuclear membrane such as bacteria.

Student-: I think there is no specific answer to this because there is much research. If you take these prokaryotes as cells that do not have a membrane-bound organelle and a true nucleus. Because all the definitions contained the same meaning it is just that they used different traits.

Lecturer-: Thank you so much for your discussions. I will answer your questions okay? Eukaryotic cells contain membrane-bound organelles. Including the nucleus. The nucleus is big, and you will see it when you look at the cell under the microscope. They can be single-celled or multicellular. Following that we need to look at the structure of a prokaryotic cell

[Shows a colored 2D picture of a prokaryotic cell and a TEM picture of a prokaryotic cell]

Lecturer-: Bacteria and Archaea were placed together for a long period it was only seen recently that they are different. So, in the picture is a typical diagram of a bacterial cell. A bacterium on the left is something like a picture and on the right, it is an image. A microscopic image the left one is a picture and the right one is a picture taken using the electron microscope. The easily visible features that you can see. Not all prokaryotic cells

have flagella. I'd like you to think of the big structures that are unique to these organisms. They do have flagella some of them have flagella and flagella are used for locomotion, for movement. When flagella beat the bacteria moves in a certain direction. The flagella are for propulsion either for pushing or pulling. The bacteria are attached to the cell wall, a cell wall made up of a substance called fimbriae however some bacteria from desiccation and other forms of damage. But inside that cell wall, there is a cell membrane so if you look at this diagram the capsule is like a gel-like outer coating which is found in some prokaryotes. The cell wall is a rigid structure that is found outside the plasma/cell membrane and plasma, or cell membrane is the one that contains cytoplasm. Inside the cytoplasm are the ribosomes whose purpose is to always be responsible for the synthesis of proteins. They are complexes because they are granular, and they are made of two grains. We are going to talk about that structure, but I need to mention that the ribosomes found in prokaryotes are 70s ribosomes. They are smaller than those that are found in eukaryotes those that are found in eukaryotes are 80s, the s stands for subunits. I think one Sweden scientist discovered that he could centrifuge prokaryotic ribosomes and they settled in the 70s. Those in eukaryotes are bigger and centrifuge at 80s. The cell does not have a nucleus. Remember ribosomes are just granules. Granular structure, then the nucleus, someone asked about the nucleus where is the DNA found? The DNA is not in the nucleus it is found floating in the cytoplasm. It is found in one region called the nucleoid region. Some love to say the DNA in prokaryotes is naked, naked DNA. DNA in prokaryotes is one circular structure whereas in eukaryotes there are many. If you people each of your cells has 46 chromosomes and each chromosome is made up of DNA molecules and proteins you have at least 23 pairs of chromosomes and DNA molecules which is not the same in prokaryotes they only have one which is the bacterial chromosomes and some of them have structures that allow them the substrates and they are called fimbriae one is called a fimbria. What we have here is a typical bacteria or typical prokaryotes but not all prokaryotes have these features. Only I am done with prokaryotes… Any more questions?

Student-: Sir what I wanted to ask was that isn't it what we know that the nucleus contains and therefore, that is where DNA is located? Prokaryotes have no nucleus and membrane membrane-bound. Where is their nucleus located? But you answered by saying it is located in their cytoplasm, I think.

Lecturer-: My correction is that they do not have a nucleus, but the DNA is floating in the cytoplasm, and I need to mention prokaryotes have more than one set of DNA that the other set is called plasmids. Plasmids have DNA which can easily mutate. I'm sure some of you have heard that you don't have to take antibiotics every time you get sick this is because if you continue taking antibiotics the bacteria plasmids are likely to develop resistance to the chemicals that you are giving them and then one day wake up with a bacterial infection that is not treatable because the bacteria have learned how to fight chemicals you are using to destroy it. In most cases, the ability to fight off the bacterium is found in the plasmids so guys when you get ill don't just rush to get antibiotics. You create variants of a bacteria in you. There are many variants of PPNG- Penicillin produced in gonorrhea.

[Showed a picture of bacterial DNA and plasmids]

Lecturer-: So, there is a structure that shows bacterial DNA that is the main cellular DNA and then on the other side it is showing you plasmids. Can be one or more different plasmid inside. Each plasmid is a circular DNA.

[Shows a 2D labeled diagram of a prokaryotic cell]

Lecturer-: Yes, this is the same diagram, I was talking about but there is an addition on the left here. The addition is showing the cell membrane in prokaryotes bas invaginations and those folding are called mesosomes and those mesosomes are responsible for respiration. So we are going to talk about mitochondria, mitochondria being an enclosed region but these are not enclosed they are just infoldings of the membrane in there where respiration takes place. It is not exactly simple, the organelle is not that simple. They do not have membrane-bound organelles.

Student-: Can you please repeat, I only heard the part about mesosomes being the site for respiration.

Lecturer-: The cell membrane or plasma membrane has regions where it is folded inwards into the cytoplasm and those infoldings are called mesosomes. And mesosomes are responsible for respiration just like we have the mitochondria in Eukaryotes. Right any comments on prokaryotes?

Student-: Is it correct to say prokaryotic cells are single cells containing a single set of chromosomes and eukaryotic cells are diploids, I don’t know how many cells.

Lecturer-: No that’s not correct. Prokaryotic cells are diploid.

Student-: Are prokaryotic cells diploid?

Lecturer-: Yes, the diploid young man has to do with having parents, two parents' DNA. Some prokaryotes are haploid and some prokaryotes are diploid. We are not talking about haploid-diploid here, can you leave that one out at the moment? It doesn’t operate with prokaryotic cells.

Student-: The reason I am asking is that someone asked how many sets of chromosomes a prokaryotic cell has so according to my understanding prokaryotic cells have one chromosome hence I was saying they are haploid.

Lecturer-: No when you say you say cells are supposed to have two when they are haploid, they have one. Your body cells have 46 chromosomes then your sperm cells have 23 chromosomes, and your sperm cells have a haploid number of chromosomes. You can use haploid and diploid in that case but is their normal structure so you cannot talk about haploid diploid here.

Student-: Sir, may I please say something? Is it okay to say prokaryotic cells have one chromosome?

Lecturer-: Yes, that is what is normal about them.

Student-: Say, I believe you cannot use the words haploid and diploid in bacteria because they reproduce by binary fission and not sexual reproduction. Because these cells grow and mix by cell division called binary fission.

Lecturer-: Yes, that is correct but you also need to know that they can have sexual reproduction they can exchange DNA material. When cell A and cell B not necessarily male and female lie next to each other, they can exchange genetic material. It is not always asexual. Whatever is exchanged is integrated into the circular DNA it doesn't stand on its own. It comes in and it joins and becomes part of it. Okay (*calls another student's name*)

Student-: Is it possible for prokaryotic cells to come together to form a huge organism>

Lecturer-: No. I have mentioned that they join and when they join through pili and exchange genetic material and whatever is donated and integrated into the circle, but they cannot join together to form a huge cell. For reasons, we've already talked about. Do you remember?

Student-: Yes

Lecturer-: Thank you

[Lecturer plays a video about prokaryotic cells]

Student-: Sir, I would like to know what he meant when he said that the cell wall and cell membrane contain something what do they contain?

Lecturer-: I don't know. Is there anyone to help with the difference between a cell wall and a cell membrane?

Student-: No sir, I am not asking that he said the cell wall and cell membrane contain saccharide I think something. I remember learning that the cell wall contains cellulose and the cell membrane contains proteins, so I wanted to get clarity on that.

Lecturer-: I think he said saccharides.

Student-: Yes

Lecturer-: Anyone who knows what saccharides are?

Student-: Saccharides are sugars, Sir.

Lecturer-: Sugars so?

Student-: Saccharides are sugars found in the cell wall

Lecturer-: Saccharides are sugars. Cell walls are mainly made of polymers of sugars and other substances such as murine. We'll get there, what we were talking about…. When we talk about the differences between cells, we are highlighting the differences between living things. When we are identifying organisms as prokaryotic, we are grouping them into two large groups. One group is prokaryotic organisms then another huge group is eukaryotic.

APPENDIX THREE

Blue button lesson two transcription
Lesson topic: Cell structure and function
28/02/22

Lecturer-: Good morning class, how are you? Welcome to this session. In this session, we are talking about structure and function, parts of organelles. I have decided to take the back step as I told you and you are taking the front row and are teaching us as I have mentioned it is not an assessed activity it is a voluntary activity but it helps you to interact with each other formally because you have been interacting in a non-formal way such as just greeting and others showing off their faces but this time we would love to interact more in ways that are more productive to the community. This is our learning community for NS1 for this year, and we would like to start interacting at that level it is some form of micro-teaching because you are starting to become teachers, and you start testing yourself on your ability to plan work and implement that work. Planning is a meticulous process; it is an interesting process. There is a lot that happens behind the scenes before your teacher comes to the front. It may not happen in terms of material like lesson plans and PowerPoint presentations being there or any other material being there but the thought behind the teaching is what is very important for any educator from any level when an educator starts thinking ahead about what they are going to teach. What concept are they going to teach and how are they going to teach them after they have taught, all educators go through a process of reflection which is a reflective activity. After all of this, I'm going to ask you to share your reflections in the discussion forum where you are asked to share some of your reflections to say how it went. How did you see the process of planning to teach, teaching, and the reflections that come after? So, what is interesting to a teacher is the purpose of any teaching, so I was asking you as we were getting

along yesterday with the animal. I started with the animal cell because that is what should be familiar to you, as animals you should be interested in that, and then you should want to know how they look and what they contain, etc. I started with the animal cell before I went to the plant cell, I did that strategically. And then I was asking you questions, there were two questions I was asking you and these were questions that I thought about before I started teaching. I asked you what you thought your learners should know, every time you look at the content you are saying out of this content what should my learners know. And then the next question is how my learners should know and that is part of teaching. We are not covering how to teach this year because you'll do that upon becoming a teacher but as you go through, I always want you to refer to some of this work because you need to be thinking about the content you are using when learning becoming a teacher and the question will always be what do you want to teach? For what purposes? And how do you want it to unfold? You are the teacher and have what they call pedagogic authority. I also thought it was strategic for me to ask you to work in groups because theories (learning theories) especially sociocultural theories you'll learn about them, were started mainly by Vygotsky in the 1930s who thought that learners learn better when they learn together. So they learn better if they start by learning together, then they get to learn individually. So learning starts at the social level or social plane and then it becomes an individual level when the learner becomes more confident with what they are expected to do. So right now and for the greater part of the course, we advocate that you work in groups. It works if we organize you so that most of you can interact but it also helps you to learn that you hold each other's hand, it is the supportive mechanism. I liked it when we started off talking about Natural sciences quite a number of you started looking out for group members to study with, yes think about people you can work with because you can learn better. Some people have independent approaches to learning but at times you may have these misconceptions but they are corrected by your colleagues before they come and get into the exam. So we would like you to learn together, use those groups for learning together don't just use those groups for socializing. But the groups should be primarily for learning Natural sciences. I have received the PowerPoint presentations. For the time being, I would like to invite presentations… Let me start with the nucleus people. (*Calls students names).* Who would like to come in first? Who volunteers to come in first?

[*Student projects a recap slide]*

Student presenter -: Welcome to yet another splendid life sciences lesson, sit down and relax.. this is going to be the best lesson you'll have. Just a reminder, a prokaryotic cell does not have a true nucleus and a membrane that is enclosed whereas a eukaryotic cell has a nucleus and an enclosed membrane, and all cells have a jelly-like fluid called the cytoplasm, have genetic material, and a cell membrane which separates the cell from its environment. So prokaryotic cells are small 70s whereas eukaryotic cells have 80s chromosomes meaning eukaryotic cells are larger than prokaryotic cells. As you can see here the ribosome has a structure and inside the nucleus, we have a structure called the nucleolus that's where the ribosomes are formed, after the ribosomes form and attach to the rough endoplasmic reticulum and not the smooth one. The function of the ribosome is to synthesize protein synthesis, meaning that's where proteins are formed. I hope that is …. Am I too fast?

Lecturer-: no you are not

Student-: please move to the next slide

{*On the discussion forum students are writing that they cannot see the picture}*

Student presenter-: these are references of where I took information from.. just a reminder that if you took someone's information always remember to reference it because it is not your information you took it from someone else. Thank you, Sir.

Lecturer-: Thank you for the first lesson, unfortunately from my side, the slides have not been moving. I want to take you back to slide number two may you please go back to slide number two

(*Student presenter projects slide number two)*

Lecturer-: Yes, what is the title of this lesson? What are you presenting? What did you present? Ribosomes? And if it was ribosomes what is the purpose of the first slide? What is on the first slide? Are those ribosomes? Are you going to answer me? Is that what ribosomes look like? *(calls student presenters name)*

Student presenter-: Sorry sir I muted. I didn't see that I was muted. This is a cell picture, isn't it we are talking about cells so I used this picture for more like yes…

Lecturer-: for what?

Student presenter-: the second slide was a reminder of what we talked about before so that we cannot forget them because they are important, this is what all cells have that's why I included this.

Lecturer-: and the third one?

Student presenter-: this is where my presentation is mainly focused on, we talked about where ribosomes are formed where they attach to and what are the ribosomes

Lecturer-: right, whom did you work with?

Student presenter-: I did not work with anyone. I wanted to use lysosomes but then I asked on the group and no one responded so I used the one for ribosomes.

Lecturer-: okay. Thank you very much for this because we are going to be talking about the presentation. I would like to comment that the first part of your slide is not necessary and that drawing would cause misunderstanding amongst learners, if you are talking about ribosomes the first picture you are supposed to show your learners is about ribosomes not about your excitement about Natural sciences so in future when you are working with any concept may you please project that concept and then it comes again to your second slide, you started talking about prokaryotic cells about them having a nucleus and a membrane, yes that is correct but it is not necessary when you are talking about ribosomes.

Student presenter-: yes sir it was just a reminder because the day before we were talking about prokaryotic cells so it's more like a quick reminder so that they cannot forget.

Lecturer-: that is not your role. Your role is to talk about that organelle which is called the ribosome. So the last part of slide number 2 which is the last statement is the statement that

you were supposed to use that is valuable because you are talking about ribosomes. That ribosomes are found in prokaryotic and eukaryotic cells that's number one and then number two you are going to say, prokaryotic ribosomes are smaller and there you left "ribosomes" whereas eukaryotic ribosomes are bigger and they are 80s. And that chromosome there makes it wrong, so when you say "Prokaryotic are small 70s and eukaryotic is 80s chromosome " the statement is already wrong, you are teaching the learners wrong information. And this is where group work helps now my child, you undergo a process that is called argumentation you are going to hear about it in learning to be a teacher. There's a process called argumentation the arguments you make in a group to arrive at a correct answer. This is what is beneficial about working in a group. So I would like your classmates to thank you for having the courage to come first but they need to be careful with what you presented to them because it is not very correct, I would like you to correct that and send it through for sharing. (*calls a student's name, are you ready?)*

[Lecturer projects slides for student presenter 2]

Student presenter 2-: Yes I am

Lecturer-: I will make you the presenter now

Student presenter 2-: okay sir… *The presenter calls the names of group members*. I'm going to be speaking about the nucleolus good morning, everyone. Sir, can we move to the second slide so that everyone can see the picture of the nucleolus that we are going to be talking about instead of talking about something you have never seen before? So, the first image on your left will be most likely from a microscope, and the second image is also probably from the microscope this one has a description which is proteins and nucleic acids, this is also a site for transcription and the assembly of proteins occurs… *Sir, please move to the next slide…*
This is where we will talk about what a nucleolus is, so the nucleolus is a structure, a body, a sub organelle it is not a main organelle it is found inside the nucleus, and it is responsible for ribosome production and assembly. The ribosome is assembled and transferred to the cytoplasm of the cell where they function as protein synthesis sites. Now as I said the nucleolus is a sub organelle and it is not membrane-bound, it is found in the main organelle "the brain of the cell" the nucleus. *Sir, please move to the next slide…*

(Shows a 3D image of a nucleus and a 3D image of an animal cell)

where we will talk about… oh it's a picture of where you can find the nucleolus. Moving from the cell if you are going into the cell and you want to find its location you are going to the nucleus which is the bigger body, and the nucleolus is inside the nucleus where it takes 25% of the nucleus's volume. *Sir, please move to the next slide…* where we can talk about the difference between the nucleus and nucleolus, these two are closely associated because you find the nucleolus inside the nucleus so some may make the mistake of making them the same thing when they are not, so they first differ in structure, the nucleus is a large body with a spherical shape. The nucleolus however is diffused, and it is not membrane-bound it is tiny which is present I am the nucleus. The nucleus is the cell's brain because it directs all of the functions of the cell, and the nucleus directs all the processes and functions of cell. Especially if you look at protein synthesis, but the nucleolus however is only responsible for the synthesis of ribosomes. Now the constituents are what make up these organelles, the nucleus has a chromatin network made of DNA, nuclear membrane, nucleolus, and RNA. The

nucleolus is made up of the fibrillar center, densely fibrillar element, granular component, and ribonucleic acid. The positioning also differs the nucleus is usually positioned in the center of the cytoplasm whereas the nucleolus is inside the nucleus. The genetic material also differs the nucleus contains DNA and the nucleolus contains RNA. Moving onto the next slide. We going to talk about the function of the nucleolus. The main function of the nucleolus is the facilitate the process called ribosome biogenesis during biogenesis ribosome biogenesis ribosomes are produced and assembled for protein synthesis, in the nucleolus is also responsible for making ribosomal ribonucleic acid rRNA. Moving onto the next slide we are going to dive deeper into ribosome biogenesis. Ribosome biogenesis is the process of making ribosomes in eukaryotes the process takes place mainly in the nucleolus and can also occur in the cytoplasm. The process involves the coordinated function of over 200 proteins in the synthesis and processing of the four eukaryotic RNA. Namely rRNA, tRNA, and RNA. Can you please move on to the new slide? We have the characteristics of the nucleolus the nucleolus is a distinct structure present in the nucleus of eukaryotic cells, The nucleolus is made up of dense RNA and proteins. The nucleolus is a dynamic membrane list structure, the size of the nucleoli may vary from 0.2um to 3.5 um, the average size being 0.2um, there may be one or two nucleoli present in a cell, however, humans only have one nucleolus present in the diploid cell. The nucleolus makes up the largest part of the nucleus, taking approximately 25% of the volume of the nucleus.
Moving on to the next slide

(Projects a 2D labeled drawing of a nucleolus)

This is a drawing of a nucleolus, as you can see it has an irregular shape which shows it doesn't have a membrane, and a granular component, the dense fibrillar component surrounds the fibrillar center and now I want to go further and explain what each part does. *Please move on to the next slide*

So this is how each component will contribute to the main function of the nucleolus. So the nucleoli consist of three distinguishable regions: the Fibrillar center, dense fibrillar component, and granular component. These different regions are thought to represent the sites of progressive stages of rRNA transcription, processing, and ribosome assembly. Fibrillar centers contain rRNA genes with transcription occurring at the boundary of the
Fibrillar centers Fibrillar component - processing of the pre-rRNA is initiated in the dense fibrillar component. Granular component- the rRNA is assembled with the ribosomal proteins to form nearly completed pre-ribosomal subunits, ready for export to the cytoplasm, as someone mentioned the ribosomes will attach to the rough endoplasmic reticulum but some do float around inside the cytoplasm. *Moving onto the next slide…*

Lecturer-: Before you move on to the next slide can you possibly highlight the order in which these three happen?

Student presenter 2-: So, the order is when it starts with the rRNA, the genes in the fibrillar center which are going to code for transcription along the border of the fibrillar center, now as I have said the fibrillar component surrounds the center and these codes rRNA genes are going to move into the process of pre rRNA around the boundary of the fibrillar center and then when the process begins in the granular component that is where the RNA has assembled with the component making proteins, they move out of the nucleolus and nucleus to the cytoplasm where they develop to be ribosomes which are functioning well.

Lecturer-: okay thank you

Student presenter 2-: That is the end of the lesson, the expectation for the end of the lesson is that you know what the nucleolus is, what it does, what is it it's function, different parts of the nucleolus, and how they play a role in ribosomal biogenesis. Lastly, here I have references on where I got my information and the last link here is a video that explains further what a nucleolus is and where it is found. Thank you

Lecturer-: Thank you very much (mentions the name of the student, and your team)… that was very very very detailed and interesting, yes the nucleolus is found inside the nucleus and it is the site for protein synthesis sorry ribosome synthesis. We said ribosomes, are bodies that are built out of ribonucleic acid which means they are derived from strands of ribonucleic acids that are tightly packed of ribonucleic acids. And we just heard the process here… so what processes take place are what was presented to produce ribonucleic acids which are necessary for making ribosomes but that ribonucleic acid is a messenger it's coming out of deoxyribonucleic acid. But that DNA transcribes to RNA, and ribosomal nuclei acid moves out of the nucleus and makes ribosomes. Any questions from the floor? I didn't ask questions in the previous one but now I'd like some for clarity. If there are no questions we move on to the next presenter, who would like to present next?

Student-: Hi sir, yes I have a question. You said something about the DNA being inside the nucleolus and unwinding to be rRNA, I didn't understand that part. Can you please repeat it?

Lecturer-: okay DNA exists as a tightly coiled strand, it is a double strand that is tightly coiled and for it to be able to copy itself it has to unwind first so that it becomes a straight double chain. So that it looks like a train railway line, imagine if you want a train to move on its railway line but the railway line is coiled into a spring, for the railway to be useful it has to be unwound and straight. This is the same process that DNA undergoes. It unwinds and becomes straight; it is only when it is straight is the process of transcription is possible. Transcription or copying DNA into RNA, in this case rRNA can only take place when DNA is unwound.

(*Calls the student's name) ….*

Student-: I and my team are ready to present…

Lecturer-: Thank you, okay. (calls *a student's name*) is it a question?

Student-: I would love to present…

Lecture-: what are you presenting?

Student-: the centrioles

Lecturer-: Are you presenting from there?

Student-: I can try..

Lecturer-: do I have it?

Student-: yes you have it was sent last night.

Lecturer-: yes I have it, do you want to try to present it? Let me present it to you.

Student-: Sir I was asking if that is a nucleolus found in both prokaryotic cells and eukaryotic cells.

Lecturer-: No ,

Student-: So it's only found in eukaryotic?

Lecturer-: well let me hear from the others.

Student presenter 2 -: can I explain, the nucleolus is not found inside a prokaryotic cell as we all know that the prokaryotic cell has no membrane-bound organelles inside now the space of the DNA region what we would liken to a nucleus is called the nucleoid. So, inside the nucleoid, there is no nucleolus.

Student-: thank you that was the confusion.

Lecturer-: Thank you there is no nucleolus in prokaryotes, the nucleolus is a eukaryotic feature.

APPENDIX FOUR

Blue button lesson three transcription
Lesson topic: Cell structure and function
01/03/22

[*The lecturer projects slides for the student presenter 3]*

Student presenter 3-: Good morning to my fellow students. I'm the presenter for my group. These are the names of my group members. First I would like to take you through the content of our definition, region, structure, functions, and diagrams and share recommendations where you can get more information about the centriole. First, we are going to talk about the definition of a centriole, I have a diagram with me whereby you can see the structure and another structure here is the animal cell. Centrioles are two cylindric, rod-shaped microtubular structures, near the nucleus. They are not present in prokaryotes, red algae, yeast, cone-bearing, and high flower plants, and also non-flagellated or ciliated protozoans (such as amoebae). Centrioles form a spindle of microtubules, the mitotic apparatus during mitosis or meiosis, and sometimes get arranged just beneath the plasma membrane to form and bear flagella or cilla in flagellated or ciliated cells. *Thank you next slide*

On the region of the centrioles are located in the cytoplasm of the animal cell near the nuclear envelope for them to aid in cell division by facilitating the separation of chromosomes. As we know in the nucleus there is going to be cell division so the centriole will be there to facilitate the division. They are surrounded by a highly ordered mass of dense material called the peri centrioles material (PCM) making up the structure called the centrosome. *Thank you*

(Lecturer changes the slide)

Right, as you can see it is made up of tubular-like structures. Okay The centrioles are made up of nine circular arranged triplet microtubules, and a protein called tubular is found inside. The centrioles are 0.15um to 0.25um in diameter and 0.3um to 0.7um in length. Even though some are 0.16um in diameter
And 8um long this enables the centrioles to be visible under a light microscope and enables them to lay at right angles to one another. If you look at the diagram you can see that a right angle to be formed. An electron microscope would be needed to have a more detailed vision of the centriole since it has a better resolution, The structure of the centriole enables it to perform all its functions. *Thank you.*
(Lecturer changes the slide)

The functions of the centrioles are involved in the formation of the spindle apparatus which functions during the division of cells. Divisional errors and delays in the mitotic process may occur in the absence of centriole. Centrioles are responsible for ciliogenesis which is the formation of cilia and flagella in the surface of the cell. Cilia and flagella help in the movement of the cell. Centrioles contribute to the motility of different types of cells to sense incoming signals and respond appropriately.

(*Projects 2D labelled drawings of centrioles)*

I do not know if on your side they are visible, but these are drawings of the centrioles. The one on the left-hand side there is the external structure of the centriole and the one on the right is the internal structure.

These are some of the links I saw on YouTube you can watch about how the centrioles function in the cell. Thank you everyone for listening.

Lecturer-: thank you very much, sorry you could not present from that side I also had a challenge here. What is interesting is that this is an animal cell organelle, it is only found in animal cells. You must take note of that because we are going to ask you where these organelles are found and where they are not found.

Student presenter 3-: okay sir, on on which these organelles are not found I think I have mentioned in the origin where I said they are not found in the prokaryotes, algae, and other high plants. They are not present there; I do not know if anyone is having a challenge in understanding that.

Lecturer-: Yes, thank you. We… that's what I'm emphasising, when we are going to ask you questions in exams, we are going to ask you where they are found and where they are not found, and we may ask you about the structure and function as well. : so, centrioles …

(lecturer projects a 3D image of centrioles)

I'm projecting this image because it is speaking to a structure, I want you to know and understand. The centrioles exist in pairs, and their units are always at right angles to each other, all the time there are two centrioles, they are sitting at right angles to each other. Please do not ask me why, I do not know why but this is how they are always. It's not like this diagram has been made for two different centrioles but this structure you are seeing here is describing one set of centrioles. Every time you indicate a centriole in a cell you are referring to a pair, two of them when they are together and these two for each one of them, have nine triplets of microtubules there are three that form a triplet and there will be nine of them on the outside. And inside there, there is a pair there is two triplets where you put that tube. They show nine plus two arrangements of microtubules, the nine describes the ones on the outside. nine triplets of microtubules on the outside, and then the two describe the two sets of triplets that are found inside so centrioles display a 9+2 arrangement of microtubules. That is one part that is not added there. These microtubules are built out of a protein called tubulin, so tubulin units are used to build microtubules and each of those tubules is associated with two others to form a triplet and as given centrioles are 0.25 micrometers in diameter and they are 0.3 micrometers, 2.7 micrometers in length. So, they vary in length and diameter depending on the animal species and the cells and a few could be having the diameters I've mentioned elsewhere. Centrioles are associated with microtubules and microfibres around them, and that structure is called a centrosome. Microtubules are found within a centrosome, some of you will end up asking what the relationship between a centrosome and centrioles is. Centrioles are found within a set /collection of microtubules, there will be microtubules around there. And that whole structure which has microtubules inside it and microtubules around it is around a centrosome. And that "soma" is a body again, Thank you.

Student presenter 3- Sir thank you I'm very glad that you highlighted the differences. Between centrioles and centrosomes.

[*Lecturer struggles to project the presentation, but eventually manages to project with the help of students]*
Lecturer-: is it showing yet?

Students-: yes Sir

Student presenter 4-: Good morning (student mentions their name and group members' names).For the next slide, please

(*lecturer changes the slide)*

(Projects a 2D diagram of a plant cell)

Student presenter 4-: The plant cell, inside our plant cell we have a diagram called the chloroplast. This is the chloroplast and this is the picture of a chloroplast *(projects a 2D image of a chloroplast)* it's got three membranes, the first membrane is the outer membrane, and it has also a thylakoid it can be found as a stack of thylakoids, a lamella, a lumen that is found inside a thylakoid. Next, please

(lecturer changes the slide)

What exactly is a chloroplast? A chloroplast is an intercellular organelle that is found in plants and contains mechanisms for the process of photosynthesis by converting light energy into chemical energy. Next slide, please...

(*Lecturer changes the slide)*

(Projects an electron micrograph and 2D diagrammatic representation of a chloroplast with notes)

The location of a chloroplast, where do we find this chloroplast? Chloroplast is found in the cells of all green tissues of plants and algae, and in plants, the chloroplast is found particularly in the internal cells of a leaf or parenchyma cells of the leaf mesophyll. This is an electron micrograph and 2D diagrammatic representation of a chloroplast. Next, please …

(*Lecturer changes the slide)*

The functions of the chloroplast. The chloroplast's primary job is to synthesize food through the photosynthesis process. Light energy is absorbed and converted into chemical energy. Chloroplast contains a component called chlorophyll. which traps sun energy and is utilized for food production in all green plants. The process of photosynthesis produces ATP (adenosine triphosphate). During the Calvin Cycle, or nighttime reaction of photosynthesis, carbon dioxide (CO2) acquired from the air is utilized to create carbon and sugar. Next slide, please…

(*lecturer changes the slide)*

The structure of the chloroplast, Chloroplasts are a lens-shaped organelle, around 3-microns(0,0003em - 0,0006em) long. It does not have a rigid shape; hence it is changeable and can occasionally grow.
contents of a chloroplast organelle are separated from the cytosol by two membranes separated by a thin intermembrane cavity. Thylakoids, which are flattened, interconnected bags, are located within the organelle forming another membranous system.
The thylakoids are stacked on top of each other like a deck of cards, forming a granum. Each stack of thylakoids is connected by a structure called a Lamella. Each thylakoid contains a Lumen inside of it.
The DNA of the chloroplast is located in the fluid outside of the thylakoids which is called the stroma. The stroma contains ribosomes and enzymes. Next, please…

(Lecturer changes the slide)

Student-: can you please try to slow down

Student presenter 4-: The Stroma of the chloroplast contains a watery-like solution a.k.a an aqueous fluid. The Chloroplast contains three membranes, an outer membrane, the inner membrane, and an
intermembrane which is located between the inner and outer membranes. Some view the chloroplast as a disk-shaped organelle, it can generally be described as a biconvex shape. Next, please

(Lecturer changes the slide)

A chloroplast is a tiny structure in the cytoplasm of plant cells that contains a green pigment called chlorophyll. They are oval shaped and they have two membranes, which are the outer membrane and inner membrane chloroplast are found in guard cells which is located in plant leaves. They are roughly I-2 micrometers thick and 5-7 micrometers in diameter. The space within the inner membrane is the stroma, the dense fluid within the chloroplast. Next, please

(*Lecturer changes the slide)*

This is a video we got from YouTube.
The video starts playing

Thank you this is the end of our YouTube video.
Why do chloroplasts have a green color? This is because they contain chlorophyll which is a vital pigment that is vital for the process of photosynthesis. The chloroplast contains chlorophyll which is a light-absorbing pigment. Next, please

(Lecturer projects a 3D image of a chloroplast with notes)
1) Inner membrane: it regulates the passage of material in and out of the chloroplast
2) Inter-membrane space: it has a
function in energy metabolism
3) Outer membrane 'allows movement
of organic molecules
4) Stroma: it is involved in the synthesis
Of organic molecules
5) Thylakoid: provide a platform for the
light reactions of photosynthesis
6) Lamella: they ensure that maximum
energy Iron

Lecturer-: Thank you very much I would like to emphasize this diagram. *(The projected 3D diagram of a chloroplast)*. In this slide, we need to start with structure and then go into function. Before we talk about the functions the learners need to know the structure and not upside down.

(Projects a colored and labeled 3D diagram of a chloroplast)

Do not be drawn into describing the function before you describe the structure. I find this slide very important and interesting in that this organelle is made of two membranes and they have been colored here differently for that purpose. So there's an outer membrane, the outer membrane is porous whereas the inner membrane is permeable. They are selectively permeable, so you have two membranes. The porous outer membrane and the inner membrane which is selectively permeable. We are going to hear from other colleagues who are going to talk about that. In this study, we are going to talk about double membrane-bound organelles, remember what I told you about the way we use words to describe processes and things when we use words like "double membrane-bound" we are saying that there is a double membrane and this double membrane binds a structure so we refer the chloroplast as a double membrane-bound organelle. It has two membranes that surround it. And then, inside it has single membrane-bound structures or membranes which are called thylakoids, these are more like flattened tubules, and a second point they are stacked on each other. And This is

where they form granum. Each one of those membranes flattened membranes is called a granum and thylakoids are found inside a space gelatinous space called the stroma, it is aqueous and gelatinous. But, chlorophyll is not found everywhere in the chloroplast it is found contained inside the thylakoid membrane. Chlorophyll is embedded in the thylakoid membranes, so one part of photosynthesis takes place inside the thylakoid membrane and the other part takes place inside the stroma. The stroma is gelatinous because it contains enzymes, it has enzymes and enzymes that are mainly responsible for photosynthesis. There will be other enzymes necessary for life, but the key enzymes found in the stroma are those responsible for photosynthesis. Particularly dark reactions of photosynthesis. Photosynthesis takes place in two phases, one light-dependent phase and the other light-independent phase. So the light-dependent phase takes place inside the thylakoids and the light-independent stage or phase is enzyme-driven it doesn't require light. It takes place inside the stroma. Anyone who can help me distinguish between these two, light-dependent and light-independent? What do we mean?

Student-: hello sir, when we say it's light dependent we are saying it requires light.

Lecturer-: Yes (*calls a student's name*). Thank you

Student-: when you say something is light dependent, it depends on light to produce or do whatever all its functions but when it's independent of light it does not depend on light. It can occur in a dark phase. That's my understanding.

Lecturer-: Thank you very much. So dependent reactions are those that require light for them to happen, that's why we always talk about photosynthesis requiring light. Because there's a stage in photosynthesis that requires light for it to happen that is light-dependent, then others may even call it the light stage but it is not the light stage it is a light-dependent stage. The dark reaction or light-independent reaction uses mainly enzymes and those enzymes are found in the stroma. So we use biological terms in ways that describe the structures and ways that describe the organisms. So when you hear some of these terms, the reason why some other people don't like biology it's because they haven't learned the tricks of learning it. The tricks of learning it are that you just have to learn the language and if you understand the language you understand the processes and it's easy for you to understand the subject and the discipline. If you are resistant, if your mind is resistant to knowing the meaning of words, the meaning of terms, then you'll find it difficult because you'll always struggle to understand what they mean. So *chloro* refers to chlorophyll, and *plast* is a word that comes out of another word called plastid. In cell biology, we talk about structures called plastids, and the chloroplast is a plastid. Thank you so much for today, I'll take a few questions then we finish.

Student-: Sir

Lecturer-: Yes (*calls the student's name*)

Student-: I have a question, I can simply say that the functions of the thylakoids I can say that it's a site for protein synthesis.

Lecturer-: it is not protein synthesis, thylakoids….

Student-: Sorry, photosynthesis?

Lecturer-: yes please, the thylakoids are the site for photosynthesis because it contains chlorophyll. The green pigment, yes. The chlorophyll pigments are found in the thylakoids that is where the light reaction of photosynthesis takes place and it is not the whole of photosynthesis, it is the light reaction. When you are in grade 12 you can say it is the site of photosynthesis and can get your marks but when you are at varsity, the thylakoid is not the site for photosynthesis but the site of the light-dependent stage of photosynthesis. So all the time we are going slightly deeper and more meticulous

Student-: okay sir I understand thank you. (*Calls the name of the student)*

Lecturer-: (*calls the name of a student who posted on the discussion pole*) What is your reflection? What do you mean I'm talking about you?

Student-: Sir, I find it very difficult to understand biology so when you were explaining how to grab biology by both hands, I appreciated it.

Lecturer-: thank you very much. These are the tricks that I have learned over the years. For me to like biology I learned that it is made… I just observed on my own I did not have a teacher… You are fortunate I'm sharing with you some of my tricks, you are supposed to be paying me for sharing my tricks… I've shared as much as possible… as much as we have noticed that we have asked our colleague here to help us with how she's studying, this is a platform for sharing. We are here to share so that we all develop together and learn together. When you study biology you look at the terms, don't be scared by the terms. some of those terms are self-explanatory they help you to understand them. So, thank you so much.

APPENDIX FIVE

Interview transcript

18 May 2022

Interviewer-: Hello Dr. How are you?

Lecturer-: Hello, I'm good thanks, and, how are you?

Interviewer-: I am good thanks. Have you read the participant information sheet that I have sent to you?

Lecturer-: Yes, I did.

Interviewer-: Do you understand everything that was stipulated in the sheet? Lecturer-: Yes. I agree with everything

Interviewer-: Can we start with the interview?

Lecturer-: Yes

Interviewer-: Okay. Can you please describe with me your typical lecture?

Lecture-: My lectures are different; each lecture depends on the concept that I'm working on. It depends on where I left it in the previous lecture therefore my lecture starts with a background of where we are coming from, and it directs us in the direction of developing that concept. I need to establish what my students know and at times I don't ask them what they know but I give them a summary of what happened in the previous lecture, and we go into the next topic and as we go through the topic, I try to engage them in question-and-answer activities and especially around meaning of terms, yes. And I do that because if, my experience is that every time I use words, they have different meanings amongst the students, so I try to help them see what I mean by the terms that I am using in the context of the topic.

Interviewer-: what is your understanding of teaching strategies that promote meaning-making?

Lecturer-: I don't think about it in my preparation, I think about helping my students to understand and there's something called knowledge and understanding. I try to build knowledge through understanding so that students do not necessarily memorize but they understand concepts in such a way that they thorn concepts at the end. I depend on the sociocultural approaches to teaching and learning by Vygotsky, I believe strongly in the zone of proximal development by Vygotsky whereupon every learning interaction recognizes that the students know something and my role is to facilitate them to expand their zone of development and I try to do that through a variety of ways which include border crossing where you look at the student having certain knowledge but then for them to understand that knowledge more deeply at times they need contextual examples, working with terms, working with other people, working in an activity.

Interviewer-: what is your understanding of engagement in meaning-making and teaching strategies?

Lecturer-: as I engage enable or facilitate knowledge, I believe in core knowledge engagement. I believe in working together to build understanding rather than being the knower, the knower concept that I am the knower, and my students are not knowledgeable. No, I don't believe in that, of course, there are times I need to give my learners knowledge I do that in most cases rather than clarify.

Interviewer-: In observing your lectures I observed four teaching strategies you used, i and going to name one that you used. You used student presentations to explain certain concepts, you taught them through guidance. What was your reasoning for using student presentations to teach cell structure and function?

Lecturer-: I can point out two key reasons and one of them is to facilitate students to own their knowledge, they are coming from high school where they are considered as learners. They depend most on the teacher, it is the teacher that is knowledgeable, and it is the teacher that is supposed to give them knowledge. But when you get to university, quite a lot of that knowledge is developed by students themselves. I do that to develop a skill in learners "learning how to learn ". Then students learn how to engage with resources to develop their understanding, that's one way. Once they have developed that knowledge as individuals, I want them to share that knowledge to learn to share amongst themselves so that they realize that they exist in an ecology of knowledge, whatever little the other one they contribute to make a whole of knowledge. It is part of the meaning-making process where even if you

understand one small piece, everyone else will contribute their portion to the knowledge. Even if you think you understand someone else can come in and consolidate that same knowledge you have, so in a way it is to help them to learn how to learn. In another way, it is to give them confidence that they are able, it is emotional that they see themselves as being able to share knowledge among themselves, and the other one my students are beginner teachers and preservice teachers. They are no life sciences students; they are undergraduate life sciences students, and they are preservice teachers. It is a methodological approach of trying to help them see their role as they are developing as they are becoming the teacher. How can they contribute to the learning of others and that contributes to their becoming of a teacher? The meaning-making is derived or built from a role modeling position, where the teacher is modeling being a teacher from the beginning.

Interviewer-: How do you see engagement in your lessons, what is it to you that informs active engagement in your online classroom? How can you see that they are actively listening not just passively?

Lecturer-: that is difficult these days, especially with online learning, but the lecturer is supposed to pause, I teach for a period and then stop to ask a few questions, and that helps them to engage. At times I look at the chats, some of them don't like to speak but there's a chat function that they can use so I help them to engage during the lecture by giving them a chance to contribute. Then afterward I put a question in the discussion session, occasionally I do that for them to contribute and that helps me to facilitate engagement even though it will be outside face-to-face interaction

Interviewer-: Thank you very much Dr for your time and effort, as well as your willingness to contribute.