EXPLORING THE STUDENTS' PERCEPTIONS OF FACTORS THAT ENABLE OR CONSTRAIN THE LEARNING OF NEUROPHYSIOLOGY AT A SOUTH AFRICAN METROPOLITAN UNIVERSITY: A QUALITATIVE STUDY

Trevor Tapiwa Nyakudya

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Centre for Health Science Education, in partial fulfilment of the requirements for the degree of Master of Health Science Education.

Johannesburg, South Africa, 2023

DECLARATION

I, **Trevor Tapiwa Nyakudya**, declare that the work contained in this research report is my own, unaided work. This research report is being submitted for the degree of Master of Health Science Education in the Faculty of Health Sciences, Centre for Health Science Education at the University of the Witwatersrand, Johannesburg. The work herein has not been submitted before for any degree or examination at any other University.

____

Trevor Tapiwa Nyakudya

Signed on the______22___________ day of________June_______________, 2023

I certify that all the methodology used in this research report was approved by the Human Research Ethics Committee (Non-medical) of the University of the Witwatersrand (HREC number: H19-10-30) and the University of Johannesburg, Faculty of Health Science, Research Ethics Committee (REC number: 01-75-2019).

CONFERENCE PROCEEDINGS AND PRESENTATIONS

The following presentations are offered in support of this research report.

1) **Trevor Nyakudya** and Shirra Moch (*Oral presentation*) Students' perceptions of learning threshold concepts in neurophysiology at a South African University. Wits Faculty of Health Science, Centre for Health Science Education. Focus on Teaching and Learning. 21 July 2021.

2) **Trevor Nyakudya** and Shirra Moch (*Oral presentation*) Analyses of students' perceptions of learning threshold concepts in neurophysiology at a South African university: a preliminary qualitative study. Physiological Society of Southern Africa/Association African Physiological Sciences 1st virtual conference hosted by the University of the Witwatersrand. 12-15 September 2021.

ABSTRACT

Some undergraduate medical and biomedical students grasp neurophysiology easily while others struggle to understand neurophysiology, suggesting that that there are factors that enhance or constrain epistemic access to neurophysiology. Students that struggle with neurophysiology concepts often fail to progress in terms of knowledge building and find it difficult to integrate and associate the control of other systems by the nervous system. The aim of this study was to explore and describe the undergraduate biomedical students' perceptions of factors that enhance or constrain the learning of neurophysiology at a metropolitan university in South Africa.

This was a qualitative descriptive study in which a general thematic analysis approach was used. Semi-structured interviews were conducted with a purposive sample of 10 male and female undergraduate biomedical students studying Physiology and registered in the Faculty of Health Sciences at a metropolitan university in South Africa. Interview transcripts were coded using MAXQDA for data management and analysed using a general thematic analysis approach. Students' perceptions of the factors that enhance or constrain the learning of neurophysiology including troublesome knowledge and potential threshold concepts were identified and described.

Findings show that students identified prior learning of biological concepts in high school, availability of learning resources and practical sessions as enhancing the learning of neurophysiology while the amount of work to be covered, language and terminology, pre-requisite knowledge of physical sciences and the existence of troublesome knowledge and potential threshold concepts were identified as constraining factors in the learning of neurophysiology. Neurophysiology topics such as somatosensory and somatomotor pathways,

functions of the different regions of the brain and special senses were recognised as troublesome knowledge while the generation and propagation of action potentials was described as a threshold concept that acted as a barrier to the learning of neurophysiology.

We conclude that exploring the students’ perceptions of the factors that enhance or constrain the learning of neurophysiology could improve epistemic access to neurophysiology knowledge. This study suggests how academics can design physiology teaching to support students in the learning of neurophysiology. Thus to improve learning outcomes in neurophysiology, it may be important to address the factors that constrain the learning of neurophysiology. Moreover, provision of targeted support and resources for students to overcome potential barriers to learning may be useful in the teaching of neurophysiology.

ACKNOWLEDGEMENTS

My MSc research report is a result of unique contributions from several individuals. As such, I would like to extend my gratitude to the following:

1) My supervisor, **Mrs Shirra Moch** (University of the Witwatersrand, Centre for Health Science Education) for her professional guidance and continued academic support over the entire period that I was conducting my research.

2) All the undergraduate students, without whose consent to be interviewed as well as their perceptions and opinions, this study would not have been possible.

3) My wife and life partner **Lavender Rudo Nyakudya**, who has been my rock and constant source of love and support. Her patience, understanding, and unwavering belief in me have been instrumental in helping me achieve my goals.

4) My beloved daughters **Stacy, Marcia and Chloe**, who have been my motivation to strive for excellence in all that I do. Your love and presence in my life have brought me immense joy and fulfillment, and I dedicate this thesis to you with all my heart.

5) My fellow postgraduate students: **Dr Dina-Ruth Lulua, Dr Thakhadu Mamashela and Dr Koketso Tshite** in the Centre for Health Science Education, thank you for your support and input provided during data collection, laughter, and friendship that helped me get through these years in one piece.

My gratitude goes to God Almighty who art above, I give glory, honour and praise for the gift of life, opportunities and all the other countless blessings that I cannot even begin to number.

DEDICATION

To the most important women in my life:

My late mother, Mrs Ena Mutembedza and my wife Rudo Lavender,

And my daughters:

Stacy, Marcia and Chloe

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

HREC:	Human Research Ethics Committee
REC:	Research Ethics Committee
TCs:	Threshold concepts
UJ:	University of Johannesburg
Wits:	University of the Witwatersrand

Organisation of the dissertation

The current research report is written and presented in a format that consists of five chapters whose content is as follows:

Chapter 1 comprises of an introduction to the study as well as a critical review of literature that is pertinent to the current study. In this chapter, the significance of Physiology and knowledge in the pre-clinical training of undergraduate medical and biomedical students is highlighted. The uniqueness and structure of neurophysiology knowledge is discussed using Middendorf's decoding disciplines and Bernstein's theory of knowledge sturcture. Core competencies in the learning of Physiology and neurophysiology as well as what it means for students to have understood neurophysiology are highlighted. The approaches by which students achieve understanding of neurophysiology are also discussed. The factors enabling and constraining epistemic access to neurophysiology knowledge as well as the challenges associated with inadequate knowledge building are discussed in detail. The learning theories underpinning this study and used to interpret and discuss the findings discussed in detail. Insights into the differences between troublesome and threshold concepts as well as the characteristics of threshold concepts are also highlighted in this chapter. Furthermore, the significance and utility of threshold concepts in medical education is discussed. This chapter is concluded by providing the problem statement, justification, aims and specific objectives of this research report.

Chapter 2 constitutes the methodological approaches that were followed for data collection and data analysis. A detailed description of the ethical considerations underpinning this study, research design, participant recruitment, data collection and interview process is provided. Data handling using MAXQDA and analysis using thematic analysis is also described in detail.

Chapter 3 consists of the research findings from the current study.

Chapter 4 provides a discussion that includes the interpretation of the major findings and contextualising them with findings from other studies. Learning theories were used to describe and explain the findings. The chapter is concluded by highlighting the limitations of the study and recommendations for future pedagogic practice in the teaching of neurophysiology.

Chapter 5 consists of all the references that were used and are pertinent to the entire research report.

The **Appendices** section consists of a set of appendices, which includes copies of ethical clearance certificates from the University of Johannesburg and University of the Witwatersrand, institutional permissions (UJ and Wits), research study information letters, research consent forms and interviews to be audio-taped, student participation information sheet, plagiarism declaration and Turn-it-in plagiarism similarity scores.

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

1.0 Introduction

1.1 Physiology and neurophysiology in pre-clinical medical training

Physiology is the scientific study of how living organisms function. Physiology, as a sub-discipline of biology, is concerned with the "*mechanisms which work within a living system*" (Tufts and Higgins-Opitz, 2009). It is a foundational subject that is covered in the first two years of medical school and it forms the basis for understanding the normal functioning of the body. Students studying towards health science degree qualifications at any South African university must study human physiology, among other pre-clinical basic medical science disciplines as part of their medical training. In fact, Physiology is an '*integral part of any medical curriculum*' (Tufts and Higgins-Opitz, 2009, Anderton and Chivers, 2016) and a pre-requisite for most healthcare science programs at several South African medical schools.

In medical training, Physiology plays an important role in providing medical students and trainee healthcare professionals with knowledge necessary for the diagnosis and management of pathophysiological conditions. Pre-clinical Physiology covers a wide range of topics, including the study of cells, tissues, organs, systems, and their interactions with the environment to maintain homeostasis. One of the fundamental physiological system that students have to learn is neurophysiology, a branch of physiology that controls other systems such as the muscular, endocrine, renal and reproductive systems among others in the human body.

Neurophysiology involves the study of the functions of the nervous system including neuronal functions, neuroglia and neuronal networks in the brain and spinal cord and the peripheral nervous system. It covers a wide range of topics, including the electrical and chemical activity of nerve cells, the organization and function of neural circuits, the physiology of sensory and motor systems, and the neural bases of higher order functions such as cognition and behaviour (Verdugo and Matamala, 2022). The nervous system, an integral part of neurophysiology, is one of the control systems in the human body whose function is regulate the other systems as they maintain homeostasis. Unlike the endocrine system, which is slow acting, the nervous system is a fast-acting control system, responsible for regulating other physiological systems in the body. All the physiological systems in the human body work together to maintain homeostasis, an important phenomenon in the teaching of medical Physiology (Meek and Jamieson, 2014, Neve et al., 2016).

Neurophysiology is a crucial component of medical education because it provides undergraduate medical students with a deep understanding of the normal functioning of the nervous system and how it relates to various neurological disorders (Haneef et al., 2017). During their pre-clinical years, biomedical and medical students frequently receive training in the basic principles of neurophysiology which include topics such as the electrical and chemical activity of nerve cells, the physiology of sensory and motor systems, and the neural bases of cognition and behaviour. Lectures, tutorial and practical sessions are the pedagogical tools that are used to teach the basic neurophysiology concepts. This pre-clinical training provides a foundation for understanding the normal functioning of the nervous system and for the diagnosis and management of neurological disorders, which are among the most common and debilitating conditions that affect human health (Gupta and Grover, 2021).

During their clinical years, medical students have the opportunity to participate in neurophysiology rotations or electives. These rotations typically focus on the application of neurophysiology to the diagnosis and management of patients with neurological disorders.

Ability to apply neurophysiology during clinical training requires a deep understanding of basic neurophysiological principles. Medical students may also have the opportunity to participate in research projects related to neurophysiology, which can provide valuable experience for those that wish to pursue a research career in neurosciences.

1.2 Middendorf and decoding disciplines: uniqueness of physiology and neurophysiology knowledge

What makes neurophysiology know unique from other disciplines?

Physiology is a discipline that seeks to understand the mechanisms that allow living organisms to survive and thrive, and it is an important field of study in the life sciences, including medicine, biology, and biochemistry. This makes physiology knowledge specialist knowledge that is unique as it focuses on the study of the function and properties of neurons and neural circuits. It requires advanced training and expertise in biology, physiology, and neuroscience, among other fields, to understand the complex workings of the nervous system. The integrative and regulatory nature of the neurophysiology requires students to develop a clear understanding of neurophysiological concepts and the implications of neuropathology in the dysregulation of other physiological systems throughout the body (Wenger, 2010). Understanding neurophysiology is considered a core competence in pre-clinical medicine and biomedical sciences.

Middendorf's decoding disciplines is a framework that can be used to understand the unique features of different disciplines and how they contribute to knowledge production (Middendorf and Pace, 2004). According to this framework, neurophysiology, as a decoding discipline, can be considered as a combination of all four decoding disciplines (Esterman et al., 2009).

a) *Synthetic:* Neurophysiology focuses on the integration of information from different sources to form a comprehensive understanding of a topic. To create a thorough understanding of the nervous system, neurophysiology combines knowledge from other disciplines, including anatomy, biochemistry and pharmacology.

b) *Analytic*: Neurophysiology puts emphasis on the breakdown and analysis of complex phenomena into simpler components. The complex functioning of the nervous system is broken down into simpler parts by neurophysiology, including the electrical and chemical activity of nerve cells, the structure and operation of neural circuits, the physiology of sensory and motor systems, and the neural bases of cognition and behaviour.

c) *Pragmatic*: Neurophysiology focuses on the application of knowledge to solve real-world problems. Neurophysiology knowledge can be applied in solving real-world problems by providing the understanding of the diagnosis and management of neurological isorders.

d) *Hermeneutic*: Neurophysiology discipline focuses on the interpretation of meaning and understanding of complex phenomena. Neurophysiology also provides an interpretation of the meaning of the neural activity, and the understanding of the neural basis of the functioning of the nervous system and how it controls other physiological systems.

Neurophysiology therefore is a decoding discipline that combines all four decoding disciplines in order to comprehend the distinctive characteristics of the nervous system and how it functions as well as to address practical issues pertaining to neurological pathophysiology.

1.3 Core competencies in neurophysiology

Considering the skills and knowledge that students are expected to possess at the end of their pre-clinical training, the main question that arise is:

What competencies or set of skills should students possess to have learnt neurophysiology?

There are a lot of core principles that undergraduate students are expected to possess for them to be considered to have adequately mastered physiology and indeed neurophysiology (Zanden et al., 2019). Some of the criteria and expectations in medical training include acquisition of knowledge ranging from factual, theoretical and practical knowledge as well as the competencies and skills in specific areas or topics of medical physiology (Shulman, 1986). Students who enroll for undergraduate health sciences studies at South African universities, gain and use specialized knowledge to understand physiological mechanisms and how the different body systems are related to each other and how they all work together to maintain homeostasis and disease progression.

At the end of their pre-clinical Physiology training, the students are expected to have gained knowledge on several basic physiological mechanisms and theoretical concepts on pathophysiology for use and application during their clinical training later on (McFarland and Michael, 2020). Students are also expected to build on prior knowledge, skills and competencies, demonstrate the application of broad and specific physiology knowledge, demonstrate an understanding of basic pre-clinical test and creatively solve problems (Raymond et al., 2020). The implications of poor performance in physiology are far reaching, often leading to incomplete knowledge building and failure to progress, especially in the understanding of neurophysiology.

The core competencies in the learning of physiology according to McFarland and Michael (2020) may include: conceptual understanding, integration of knowledge, experimental design and analysis, communication and professionalism. These core competencies provide a framework for undergraduate physiology programs to develop and assess their curricula and ensure that graduates have the knowledge and skills needed for success in the field of physiology.

However, the learning of neurophysiology requires a specific range of core competencies in order to understand the complexity of the nervous system. These competencies include:

a) *Basic biological knowledge* – which entails understanding of basic biological concepts such as cell biology, genetics, biochemistry, and anatomy, which form the foundation of neurophysiology.

b) *Neuroanatomy* – which entails familiarity with the structure and organization of the nervous system, including the brain, spinal cord, and peripheral nervous system.

c) *Cellular neurophysiology* – involves understanding the knowledge of how neurons function at the cellular level, including how they generate and transmit electrical signals and communicate with other neurons and non-neuronal cells.

d) *Systems neuroscience* – entails the understanding of how different regions of the brain and nervous system work together to process information, regulate behaviour, and control bodily functions.

e) *Neuropharmacology* - involves understanding of the effects of drugs and chemicals on the nervous system, including how they interact with specific receptors and neurotransmitters.

f) *Experimental techniques* – students should be familiar with experimental techniques commonly used in neurophysiology research, including electrophysiology, imaging, and behavioural assays.

g) *Critical thinking and analysis* – students should possess the ability to critically evaluate scientific literature, analyse data, and draw valid conclusions.

h) *Communication skills* – students should be able to effectively communicate scientific ideas and findings to both expert and non-expert audiences.

By developing these core competencies, students can gain a comprehensive understanding of the nervous system and its functions, which will prepare them for further study and careers in fields such as neuroscience and medicine.

1.4 Student approaches to achieving understanding of neurophysiology

Fyrenius et al. (2007b) surveyed 320 undergraduate students from a Swedish university to learn about the approaches to learning that students used and the variables that influenced those approaches in an attempt to understand the approaches students use to accomplish understanding. They used a modified version of the Study Process Questionnaire to assess the students' approaches to learning, and conducted interviews with a subset of the students to gain a deeper understanding of their perspectives.

The authors identified four main approaches to learning: surface approach, strategic approach, deep approach, and achieving approach. The *surface approach* involved reproducing information presented in lectures and readings without engaging with the underlying concepts while the strategic approach involved using study techniques such as highlighting and note-taking to meet assessment criteria (Fyrenius et al., 2007b). The *deep approach* involved understanding the underlying concepts and applying knowledge to new situations. The achieving approach involved aiming to achieve high grades by focusing on meeting external standards.

The authors found that students' approach to learning was influenced by a range of individual and contextual factors, including prior educational experiences, motivation, and the teaching environment. They argued that educators should aim to encourage deep approaches to learning by promoting a supportive learning environment and providing opportunities for critical reflection and application of knowledge.

From a neuroscience perspective, surface learning is regarded as immediate or short-term learning while deep learning is seen as a consolidation process that leads to long term changes (Goos et al., 2002). However from an education perspective, surface learning involves recalling and reproducing content and skills (Dolmans et al., 2016). Deep learning involves things like extending ideas, detecting patterns, applying knowledge and skills in new contexts or in creative ways, and being critical of arguments and evidence (Chin and Brown, 2000). Surface learning is the more information or surface knowledge that is often a prerequisite for deep learning. Students who rely on surface learning as a learning strategy often struggle to understand troublesome knowledge and overcome TCs as they often have the content, the knowledge and the information but lack the ability to relate or extend or transfer that knowledge (Beattie IV et al., 1997). The majority of the students are regarded as surface learners especially when looking at the topics that they identified as troublesome.

Deep learning involves things like extending ideas, detecting patterns, applying knowledge and skills in new contexts or in creative ways, and being critical of arguments and evidence."

Students who are deep learners, not only possess the content, the knowledge and the information, but can also apply this knowledge and link it or transfer the knowledge. The presence of deep and surface learners in a class, has implications on how the lecturers plan their lecturers and assessments for the diverse learners. Deep learning initially requires recall and use of surface knowledge and skills (Webb, 2005). Memorisation and rehearsal, which constitute surface learning often, equip students with foundations of neurophysiology. I must point out that the transition from surface to deep learning is a continuum and as lecturers we need to be aware of where the students are on the complexity of the leaning cycle from surface to deep in order to effectively assist them.

1.5 Epistemic access to neurophysiology knowledge

Epistemic access describes a student's capacity to comprehend, analyse, and apply knowledge in a given field or discipline (Davies and Mangan, 2007). Access to neurophysiology in medical education can vary depending on the institution and the curriculum. Some medical schools and medical training programs may have dedicated neurophysiology courses, while others may integrate neurophysiology into other courses such as neuroanatomy or neurology (Matthews, 2022). Additionally, access to neurophysiology education may also be affected by the availability of resources such as laboratories to run neurophysiology practical sessions or simulation centres, as well as the availability of lecturers with expertise in the field (Jirout and Klahr, 2021). It is important for undergraduate medical students to have access to comprehensive neurophysiology education, since a solid understanding of the nervous system is crucial for the diagnosis and management of a wide range of medical conditions, including neurological disorders (Trevors et al., 2017). In the following section I will discuss the challenges associated with limited epistemic access which results in fragile knowledge building and the implications on pre-clinical medical training for biomedical and medical students.

1.5. Implications of inadequate knowledge building in the learning of neurophysiology

Inadequate knowledge building because of limited epistemic access in the learning of neurophysiology can have significant implications for the training of medical students and the practice of medicine. The training of biomedical and medical students may be negatively affected by limited epistemic access of neurophysiology knowledge.

1.5.1 Limited understanding of the nervous system

The training of medical students and the practice of medicine may be significantly impacted by limited epistemic access to neurophysiology education. To guarantee that medical students have the knowledge and abilities required for providing the best care for patients with neurological disorders, it is critical that medical schools to offer full epistemic access through neurophysiology teaching curriculum design.

If medical students do not have sufficient epistemic access to neurophysiology education, they may not have a complete understanding of the normal functioning of the nervous system and how it relates to various medical conditions (Hmelo-Silver and Barrows, 2008). This can lead to difficulty in diagnosing and treating neurological disorders. Since neurophysiology module is a pre-requisite for the subsequent years of medical training, failure will result in students writing supplementary assessments and may have to repeat the module if they fail supplementary assessments.

1.5.2 Inadequate preparation for clinical practice

Undergraduate biomedical and medical students who do not receive adequate training in neurophysiology may not be well-prepared for the diagnosis and management of patients with neurological disorders. They may lack the knowledge and skills necessary to provide appropriate care for these patients.

1.5.3 Difficulty in keeping up with advances in the neuroscience field

The field of neurophysiology is dynamic and is rapidly advancing, with new discoveries and treatments being developed all the time. If students do not have full access and understanding of the latest information and research in the field, they may struggle to keep up with advances in the field, which can impede their ability to provide the best possible care for their patients.

1.5.4 Limited opportunities for research and innovation

There is usually a few students that pursue a pre-clinical research pathway such that if they have limited epistemic access to neurophysiology education it may also affect opportunities for research and innovation in the field. Medical students with limited access to neurophysiology education may not have the opportunity to engage in research projects or to pursue careers in neurophysiology-related research.

1.6 Factors enhancing epistemic access to neurophysiology knowledge

When it comes to biomedical and medical students learning about neurophysiology, there are several factors that enhance or promote epistemic access:

1.6.1 Prior knowledge and background

Having a strong background in the fundamental concepts of biology, chemistry, and physics can help students better understand and make connections with the material they are learning in neurophysiology. Prior learning of biological concepts in high school can greatly aid in the learning of neurophysiology as it provides a foundation of knowledge and understanding of basic biological principles (Mayer, 2005). Understanding concepts such as cell biology, genetics, and anatomy can help students better understand and contextualize the material covered in a neurophysiology course. Additionally, understanding the broader concepts of homeostasis and regulation can also aid in understanding how the nervous system functions to maintain these processes in the body.

1.6.2 Active learning

Engaging in active learning strategies, such as problem solving, discussion, and experimentation, can help students better understand the material and make connections between different concepts. Active learning requires students to engage in their own learning by participating in activities that allow them to construct knowledge and understanding (Brasnford et al., 2000; Chi et al., 2014). Such activities will require the students to perform higher order thinking, construct new knowledge, and build new scientific skills (Handelman ety al 2007). Therefore, any teaching and learning activity that promotes active learning will enhance epistemic access.

1.6.3 Scaffolding

Scaffolding is a teaching method that uses a gradual release of responsibility to students, starting with more guidance and support and gradually reducing it (Aggarwal and Gupta, 2021). Scaffolding can help students build their understanding of the material and develop their own problem-solving skills. It mainly involves breaking down complex concepts into smaller, more manageable components that students can understand (Anwar et al., 2021). In the teaching of neurophysiology, scaffolding can be particularly important due to the complexity of the subject matter. By providing students with clear, step-by-step instruction and gradually increasing the level of difficulty, educators can help students develop a solid foundation of knowledge and skills needed to understand the intricacies of the nervous system.

Scaffolding can also help students develop critical thinking skills by encouraging them to ask questions, make connections between concepts, and apply what they have learned to new situations (Pekmezaris and O'Connor, 2021). This can be particularly important in neurophysiology, where students must be able to think creatively and solve complex problems in order to understand the workings of the nervous system. Moreover, scaffolding can help students build confidence in their abilities by providing them with a sense of accomplishment as they successfully master each new concept or skill in a stepwise manner. This can be particularly important in neurophysiology, where the complexity of the subject matter can be intimidating for many students (Amara et al., 2020).

1.6.4 Metacognition

Metacognition refers to the ability to reflect on one's own thinking processes and to regulate and monitor one's own learning (Tanner, 2012). Encouraging students to reflect on their own learning and understanding of the material can help them become more aware of their strengths and weaknesses and make adjustments accordingly (Nakhleh, 2014). In the context of learning neurophysiology, metacognition can be an effective tool for improving understanding and retention of the material.

By engaging in metacognitive strategies such as self-reflection, self-questioning, and self-monitoring, students can become more aware of their own learning processes and identify areas where they may be struggling. For example, a student who is having difficulty understanding a particular concept in neurophysiology may use metacognitive strategies to identify the specific problem and develop a plan to address it, such as seeking additional resources or asking for clarification from the lecturer or tutor. Metacognition can also help students identify their own strengths and weaknesses, which can be helpful in developing effective study strategies (Iqbal and Sadaf, 2019). For example, a student who is particularly strong in visual learning may use this knowledge to incorporate more diagrams or visual aids into their study materials.

As a factor that enhance epistemic access of neurophysiology knowledge, metacognition can help students develop a deeper and more nuanced understanding of neurophysiology concepts by encouraging them to think critically about the content and make connections between different concepts. By engaging in metacognitive processes such as self-reflection and self-questioning, students can become more active and engaged learners, which can improve their understanding and retention of the material.

While the current study did not specifically focus on scaffolding and metacognition themes, their inclusion in the current literature review provides a broader understanding of the factors that contribute to the enhancement of neurophysiology learning. By incorporating these themes, the study encompassed a more comprehensive exploration of the topic, shedding light on the various aspects that influence students' learning experiences in neurophysiology.

1.6.5 Visual aids and online resources

Using visual aids such as diagrams, models, and animations can help students better understand complex concepts and make connections between different parts of the material. The availability of online resources can greatly aid in the learning of neurophysiology by providing access to a wide range of information and resources that can supplement traditional classroom learning (Hassan and Imtiaz, 2021). Online resources can include articles, videos, interactive simulations, and case studies that can help students understand and apply key concepts in neurophysiology. Additionally, online resources can provide access to current research and developments in the field, which can help students stay up-to-date with the latest advances in neurophysiology (Nieder et al., 2021). Online tools can also be helpful for self-directed learning and for giving students a chance to review and practice important ideas outside of the classroom (Levinson et al., 2018; Dyer et al., 2019). This can be especially helpful for students studying neurophysiology, as the subject content can be difficult and may benefit from additional practice and review.

Another important aspect of online resources is the ability to access it any time and from any location, this can be especially useful for students who have mobility issues or who may not have access to traditional classroom resources. Overall, the accessibility of online resources can significantly improve the educational experience for students studying neurophysiology by giving them access to a variety of information and tools that can support and complement their in-class learning.

1.6.6 Real-world applications and clinical correlates

Real-world applications and clinical correlates are an essential component of the teaching of neurophysiology (Wilson and Jarrott, 2019). Demonstrating the relevance and applicability of the material to real-world scenarios can help students see the value of what they are learning and make connections between the material and their future careers. The use of clinical correlates helps students develop a deep understanding of the neurophysiology concepts and promote epistemic access (Aljohani et al., 2021). By showing students how the concepts they are learning in the classroom apply to real-world situations and clinical practice, educators can help students develop a deeper understanding of the relevance and practical implications of the material. Real-world applications can include examples such as how the nervous system regulates body temperature, how the brain processes sensory information from the environment, or how the nervous system controls movement and balance (Wilson and Jarrott, 2019). By linking these concepts to everyday experiences, students can gain a greater appreciation for the complexity and importance of the nervous system in their medical training.

Clinical correlates are also important in the teaching of neurophysiology as they help students understand how the concepts are learning relate to the diagnosis, treatment, and management of neurological disorders (Hwang and Chen, 2018). For example, students may learn about how abnormal electrical activity in the brain can lead to seizures, how damage to specific regions of the brain can result in motor deficits, or how disruptions in the release or reception of neurotransmitters can contribute to psychiatric disorders.

By incorporating real-world applications and clinical correlates into the teaching of neurophysiology, lecturers can assist undergraduate biomedical and medical students develop a holistic understanding of the nervous system and its functions. This can also help students see the practical value of the material and inspire them to pursue careers in neuroscience, medicine, or related fields upon completion of undergraduate studies.

1.6.7 Laboratory practical sessions in the learning of neurophysiology

Laboratory practical sessions are an important aspect of learning neurophysiology since they provide students with the opportunity to apply and reinforce the concepts and theories they have learned in the classroom (Griffin, 2003). In fact, neurophysiology practical sessions are dominated by the use electrophysiological techniques that are used to assess the functions of neurons and detection of neurological disorders (Colthorpe and Ainscough, 2021). Practical sessions usually include hands-on experiments, demonstrations on computer software, and laboratory work that allow students to directly observe, collect and analyze data on the functioning of the nervous system (Horrigan, 2018). For example, students can perform experiments to measure action potentials, to demonstrate the concept of synaptic transmission, or to observe neural reflexes. Additionally, students can use laboratory equipment such as oscilloscopes and other measuring devices to record and analyze neural signals. Moreover, techniques such as electroencephalography and electromyography are used to assess higher order functions such as sleep patterns and behaviour.

Neurophysiology practical sessions also provide students with the opportunity to develop important laboratory skills such as experimental design, data analysis, and the use of scientific equipment (Horrigan, 2018). These skills are essential for careers in neuroscience, medicine, and other related fields. Moreover, practical sessions can also help students to better understand the relevance and applicability of neurophysiology to real-world scenarios. This can foster curiosity and interest in the subject matter and can help to motivate students to continue learning and exploring the field.

Practical sessions are indeed an essential aspect of learning neurophysiology as they provide students with the opportunity to apply and reinforce theoretical knowledge and concepts, develop important laboratory skills, and understand the relevance of the subject matter to real-world scenarios.

1.7 Factors hindering epistemic access to neurophysiology knowledge

Based on my experience of teaching physiology and neurophysiology over the past 19 years at four different universities, I have noted that some students struggle to grasp and master neurophysiology concepts. This observation has been corroborated by other physiology educators, for instance in the United States where human anatomy and physiology also seem to have a reputation as one of the most difficult modules undertaken by students studying for pre-health majors (Sturges and Mauner, 2013). In the context of learning neurophysiology by undergraduate biomedical and medical students, there are several factors that can hinder or constrain epistemic access thus acting as barriers to the learning of neurophysiology.

1.7.1 Inadequate prior knowledge and background on physical sciences

If students do not have a strong background in the fundamental concepts of biology, physical sciences (chemistry and physics), it can be difficult for them to understand and make connections with the material they are learning in neurophysiology (Guller and Sigirci, 2021). Chemistry and physics are both important in the learning of neurophysiology as they provide the foundational knowledge and understanding of the underlying principles that govern the workings of the nervous system (Michael and McFarland, 2020).

Chemistry, in particular, is important in understanding the biochemical processes that occur within the nervous system, such as neurotransmission and synaptic signalling (Michael et al., 2009). Understanding the chemical composition of neurotransmitters and how they interact with receptors is essential for understanding how the nervous system functions. Additionally, an understanding of basic chemistry and biochemistry is necessary for understanding the metabolism of neurons and how energy is used to maintain neural activity.

Physics on the other hand is important for understanding the electrical processes such as action potentials and the generation of nerve impulses, that occur within the nervous system. This includes understanding concepts such as electrical potentials, current, and resistance, which are fundamental to understanding how the neuronal and nervous system functions. Moreover, physics is also important in understanding the mechanics of the nervous system, such as the biomechanics of nerve fibres and the mechanical properties of nerve cells.

A thorough comprehension of neurophysiology and the capacity to recognize the importance of various aspects of neurophysiological principles, therefore depend on a deep understanding of the fundamentals of physics and chemistry. Lack of this knowledge may hinder students' capacity to comprehend the fundamental neurophysiology concepts that underlie the functioning of the nervous system. It will certainly be a challenge for students to understand the intricate mechanisms governing neuronal signalling, neurotransmission, and the production of action potentials.

1.7.2 Passive learning

Passive learning strategies, such as simply going through lecture notes or reading recommended textbooks can be less effective than active learning strategies, as students may not have the opportunity to engage with the material or make connections between different concepts. Passive learning refers to learning through activities that involve receiving information without actively engaging with it (Ghosh et al., 2028; Jiang et al., 2021). While passive learning can be useful in some circumstances, it also has several disadvantages, including:

a) *Limited retention:* Passive learning often leads to limited retention of information because learners do not actively engage with the material. Research has shown that people tend to forget a large percentage of what they have learned through passive learning within a short period of time (Jiang et al., 2021).

b) *Lack of engagement:* Passive learning can be boring and unengaging, which can lead to disinterest and disengagement in the learning process. This lack of engagement can result in a lower motivation to learn and reduced overall learning outcomes (Ghosh et al., 2028).

c) *Inability to apply knowledge:* Passive learning may not provide learners with the skills and knowledge needed to apply what they have learned in real-world situations. Active learning methods, such as problem-solving or critical thinking, are better suited to developing skills and knowledge that can be applied in different contexts (Jiang et al., 2021).

d) *Limited feedback:* Passive learning often does not provide learners with feedback, which is essential for assessing their understanding and progress. Without feedback, learners may not know what they have learned and where they need to focus their efforts to improve (Ghosh et al., 2028; Jiang et al., 2021).

e) *One-size-fits-all approach:* Passive learning methods tend to be designed for a general audience, which means that they may not cater to the unique needs and learning styles of individual learners. This can result in learners not being able to fully engage with the material or missing important concepts.

While passive learning can be convenient and easy, it is not always the most effective way to learn. Active learning methods that involve engagement, problem solving, and feedback are generally better suited to promoting effective knowledge building, long-term retention and the development of skills and knowledge that can be applied in various contexts (Wang et al., 2019).

1.7.3 Complexity of the material and structure of knowledge

The structure of neurophysiology knowledge is a complex subject that can be dense and difficult to understand. It may be hard for students to make sense of the material and see how different concepts fit together. According to Regehr (2020), it is a complex field that can be challenging to learn for several reasons:

a) *Multidisciplinary nature* - neurophysiology draws from several disciplines, including biological sciences, chemistry and physics. This interdisciplinary nature can make it challenging for students to integrate and apply knowledge from different fields.

b) *Technical jargon and language* - neurophysiology uses technical terms and jargon that may be unfamiliar to learners. This can make it difficult to understand and remember concepts and can hinder effective communication and collaboration between lecturers and students.

c) *Complexity of the nervous system* - the nervous system is incredibly complex, with billions of neurons and trillions of synapses. Understanding how all these components, work together to enable perception, cognition, and behaviour can be overwhelming.

d) *Limitations of current technology* - neurophysiology research often relies on complex and expensive technology such as functional magnetic resonance imaging or electroencephalography. Access to these technologies can be limited, making it challenging for students to gain hands-on experience and fully understand the underlying concepts.

e) *Limited understanding of the brain* - despite decades of research, there is still much that we do not understand about the brain and how it works. This lack of knowledge can make it challenging for students to grasp certain concepts and can lead to frustration and discouragement.

The complex structure of neurophysiology can hinder learning due to its multidisciplinary nature, technical jargon, complexity of the nervous system, limitations of current technology, and limited understanding of the brain (Larson and Lee, 2019). However, with dedication, perseverance, effective teaching strategies and curriculum design, students can overcome these challenges and develop a deep understanding of neurophysiology.

1.7.4 Limited metacognition

If students are not encouraged to reflect on their own learning and understanding of the material, they may not be aware of their strengths and weaknesses and make adjustments accordingly. Metacognition is an essential aspect of effective learning, as it enables learners to monitor their own progress, identify areas of weakness, and adjust their learning strategies accordingly

(Tanner, 2012). In the context of neurophysiology, limited metacognition in the teaching process can limit understanding in several ways:

a) *Inability to identify knowledge gaps* - without metacognitive awareness, undergraduate students may not be able to identify gaps in their knowledge and understanding of neurophysiology. This can lead to misconceptions or incomplete understanding of concepts, which can hinder their ability to learn and apply neurophysiology principles (Tanner, 2012).

b) *Lack of effective study strategies* - metacognitive awareness is crucial for developing effective study strategies that help learners process and retain complex information. Without this awareness, learners may struggle to develop effective strategies and may rely on passive learning methods that limit their understanding of neurophysiology (Chen, 2019).

c) *Inability to self-assess* - self-assessment is a critical component of metacognition, as it enables learners to monitor their own progress and identify areas for improvement. Without this ability, students may struggle to identify their strengths and weaknesses and may be unable to take steps to improve their understanding of neurophysiology (Tanner, 2012; Chen, 2019).

d) *Limited ability to transfer knowledge* - metacognitive awareness is essential for transferring knowledge from one context to another. Without this awareness, students may not be able to apply their knowledge of neurophysiology to new situations or contexts, limiting their ability to understand and apply these principles in a meaningful way (Chen, 2019).

e) *Limited ability to reflect on learning* - reflection is an important aspect of metacognition, as it enables students to reflect on their learning experiences and identify areas for improvement. Without this ability, learners may struggle to identify the underlying causes of their learning difficulties and may be unable to take steps to address them (Chen, 2019).

Limited metacognition in the teaching of neurophysiology can limit its understanding by hindering students' ability to identify knowledge gaps, develop effective study strategies, self-assess, transfer knowledge, and reflect on learning experiences (O'Brien and Opfer, 2019). Effective teaching strategies that promote metacognitive awareness can help learners overcome these challenges and develop a deep understanding of neurophysiology.

1.7.5 Limited use of visual aids

If visual aids such as diagrams, models, and animations are not used for teaching neurophysiology, it can be harder for students to understand complex concepts and make connections between different parts of the material (Nieder and Nagy, 2021). Visual aids such as diagrams, images, and videos can be highly effective in the learning of neurophysiology. They can help students understand complex concepts, make connections between different ideas, and retain information more effectively (Sherbino and Chan, 2020). Limited use of visual aids in the learning of neurophysiology can have several implications, including the following:

a) *Reduced understanding of complex concepts* - neurophysiology involves complex concepts and processes that can be challenging to visualize and understand without the use of visual aids. Without these aids, students may struggle to grasp the relationships between different parts of the nervous system and how they work together to enable perception, cognition, and behaviour.

b) *Limited retention of information* - visual aids can help students retain information more effectively by providing a visual representation of the concepts being taught. Without these aids, students may struggle to remember key concepts and may be more likely to forget information shortly after it is presented.

c) *Limited ability to apply knowledge* - visual aids can help students make connections between different concepts and apply their knowledge in new contexts. Without these aids, students may struggle to apply their knowledge of neurophysiology to real-world situations or to make connections between different areas of the subject.

d) *Increased cognitive load* - without visual aids, students may be required to process large amounts of complex information without any visual cues to help them make sense of it. This can increase cognitive load and make it more difficult for students to understand and retain information.

e) *Limited engagement* - visual aids can help to make learning more active engaging and interactive, which can increase motivation and enhance the learning experience. Without these aids, students may be less engaged and less motivated to learn, which can hinder their progress and limit their understanding of neurophysiology.

Limited use of visual aids by lecturers when teaching neurophysiology can have significant implications for understanding, retention, application, cognitive load, and engagement.

Incorporating visual aids into teaching strategies can help to address these issues and enhance the learning experience for students.

1.7.6 Limited use of real-world applications in teaching neurophysiology

If the relevance and applicability of the material to real-world scenarios is not demonstrated, it can be difficult for students to see the value of what they are learning and make connections between the learning material and their future careers. All of the abovementioned factors can work together to make it a challenge for students to develop a deep understanding of the neurophysiology material and hinder or constrain epistemic access.

1.8 Exposition of learning theories underpinning the current study

Several learning theories serve as a guide for qualitative research in medical education by providing a theoretical framework for comprehending how students learn and how teaching methods and educational interventions can be created to maximize learning outcomes. The key variables and factors that affect learning, such as motivation, student perspectives, cognitive processes, and environmental factors, can be identified by qualitative researchers in medical education by drawing on learning theories. Researchers can then investigate how these factors interact with educational interventions and instructional strategies to enhance the teaching of neurophysiology. This can assist in guiding the creation of effective educational interventions that are based on research-proven theories of learning. For the current study, the constructivism learning theory, Bernstein's structure of knowledge, cognitive overload theory and constructive alignment theory were used to guide this research. It is important to note that these theories were not used as a theoretical frameworks for the current study but were rather used to explain and support my findings from this study.

1.8.1 Constructivism theory and active learning

This learning theory suggests that knowledge is constructed through individual experiences and interactions with the environment, rather than simply being transmitted from teacher to student (Mayer, 2009). Constructivist learning theory also holds that knowledge is constructed through individual via experiences and interactions with the outside world rather than being just transmitted from lecturer to student (Bada and Olusegun, 2015). This is usually achieved by fostering active learning and engagement among the students. The term "active learning" is used to describe a teaching technique where students actively participate in the learning process through hands-on activities, group projects, discussions, and problem-solving exercises in the context of basic medical sciences like physiology and neurophysiology (Perkins, 1999). This approach supports the constructivist theory of learning because it allows students to develop their understanding of neurophysiological concepts through their own experiences and active interactions with the material (Mayer, 2009).

The constructivist theory of learning, argues that when students are actively involved in the learning process and developing their own understanding of the material (Mayer, 2009, Mintzes, 2020), they are more likely to retain and understand information, is consistent with the focus on student involvement and discovery in active learning.

1.8.2 Bernstein's theory and the structure of knowledge in neurophysiology

This theory highlights the importance of understanding the structure of knowledge in a field, and how it can be organized and classified to facilitate learning and understanding. In qualitative research, this can be applied by ensuring that the research question is clearly defined and that the data collected is organized in a meaningful way to facilitate the development of insights and understanding. Bernstein's theory of knowledge construction can be used to help students actively build their comprehension of difficult biological concepts when learning neurophysiology (Singh, 2002, Bernstein, 2003). According to Bernstein, knowledge is not simply transmitted from teacher to student, but is instead constructed through the student's experiences and interactions with the material (Maton, 2014). This also aligns with the concept of active learning, in which students are urged to actively engage with the subject matter through hands-on activities, conversations, and problem-solving assignments (Daniels, 2004).

In the learning of neurophysiology, the hierarchical organisation and structure of knowledge entail beginning with straightforward explanations and progressively building upon that foundation to investigate more complex concepts. Students can develop their understanding of neurophysiology by revisiting ideas at higher degrees of complexity as their knowledge and understanding increase according to the "spiral curriculum" method (Bernstein, 1977, Beattie IV et al., 1997). For students to investigate and build their comprehension of the neurophysiology, support and structure must be provided. To assist students develop connections and advance their understanding of neurophysiology, for instance, this can entail giving clear explanations, guiding them through practical exercises, or facilitating structured group discussions.

1.8.3 Cognitive overload theory

The cognitive overload theory posits that exposing students to too much information can result in ‘cognitive overload’, making it difficult for them to process and understand the information (Rutkowski and Saunders, 2018). Cognitive overload is the condition in which the quantity and complexity of information being processed overwhelms a person's working memory (Pappas, 2014). This happens when students attempt to learn a subject that is complex and challenging to understand. There are several implications associated cognitive overload and these include confusion, frustration, and a failure to comprehend or retain the information (Mackay, 2000).

Students may also struggle to apply what they have learnt to new situations or problems. This can lead to poor performance in assessment tasks and makes it harder for students to understand and engage with the material in real-world applications. The cognitive overload learning theory allowed me to ensure that the data collected is relevant and focused, and that the methods used to analyze and interpret the data allowed for the identification of factors that contribute to excessive information overload.

In the context of learning neurophysiology, cognitive overload can be caused by a number of factors, such as; complex and abstract concepts that are difficult to grasp, a high volume of new information presented over a short period of time, a lack of clear and concise explanations or examples, a lack of connections made between new information and previously learned material (Mackay, 2000). When students experience cognitive overload, they may struggle to retain new information, and find it difficult to understand and apply the new knowledge (Mackay, 2000, Byyny, 2016). This can lead to poor performance on exams, assignments, and other assessments, and can impede their ability to progress in the course.

Overall, cognitive overload can have a significant impact on the learning of neurophysiology by making it difficult for students to process and retain new information, and can impede their ability to understand and apply the material (Byyny, 2016). It is important for lecturers to take steps to mitigate the effects of cognitive overload in order to help students learn and retain new information effectively.

1.8.4 Constructive alignment theory

This theory suggests that the design of teaching and learning activities should be aligned with the desired learning outcomes (Biggs, 1996). Constructive alignment learning theory emphasizes on the importance of aligning the intended learning outcomes, teaching methods, and assessment tasks in order to enhance student learning (Biggs and Tang, 2021). It is based on the idea that effective learning requires a coherent learning environment where all components are aligned towards the same learning goals. The theory was originally developed by educational researcher John Biggs, who proposed that constructive alignment is a key factor in effective teaching and learning. According to Biggs, there are three main components of constructive alignment: Intended learning outcomes are the goals of the course or program, which specify the knowledge, skills, and attitudes that students should acquire. They are linked with the teaching methods which are the strategies used to facilitate student learning and achievement of the intended learning outcomes (Biggs and Tang, 2021). Teaching methods may include lectures, discussions, group work, and other activities that help students to develop the knowledge and skills required to achieve the intended learning outcomes. Assessment tasks are the tasks or assignments that are used to evaluate whether students have achieved the intended learning outcomes and these should be aligned with the intended learning outcomes and the teaching methods used in the course (Kahlke, 2014).

According to constructive alignment theory, effective learning occurs when all three components are aligned with each other. This means that the teaching methods used in the course should be designed to help students achieve the intended learning outcomes, and assessment tasks should be aligned with both the teaching methods and the intended learning outcomes (Biggs, 1996). In practice, constructive alignment can be used to design courses and programs that are focused on student learning outcomes. By aligning the teaching methods and assessment tasks with the intended learning outcomes, instructors can create a coherent learning environment that enhances student learning and achievement (Celiers and Mostert, 2013).

1.8.5 Troublesome knowledge and threshold concepts in medical education

Medical education is a field that is constantly evolving, and it is essential for students to possess the ability to understand and retain the latest information. However, this can be challenging due to the vast amount of information that needs to be covered as well as the complexity of the material which can be considered as troublesome knowledge. Troublesome knowledge refers to information that is difficult to understand or retain (Moeller and Fawns, 2018). Troublesome knowledge can make it difficult for students to understand and retain the information in the learning of neurophysiology.

Threshold concepts, on the other hand, are fundamental ideas that are necessary for understanding more advanced concepts in any discipline. The TCs are believed to have emanated from the concept of troublesome knowledge which was first proposed by David Perkins (Perkins, 2006) in his effort to explain why students regarded certain types of knowledge as difficult. According to Perkins (1999), knowledge is regarded as difficult or troublesome if it is ritual, inert, alien and conceptually difficult. Table 1 shows the different types of troublesome knowledge and their characteristics (Perkins, 1999).

Table 1.1: Types of troublesome knowledge (Perkins, 1999, Perkins, 2006)

Characteristic	**Description**
Ritual knowledge	A type of routine knowledge used for a specific task or social ritual
Inert knowledge	Knowledge that is known or understood on some level, but rarely used out of a specific context
Conceptually difficult knowledge	Knowledge that is difficult to understand at face value
Foreign or alien knowledge	Knowledge arising from a foreign or conflicting perspective
Tacit knowledge	Knowledge that is acted upon every day, but about which we may not be entirely conscious or aware

The idea of threshold concepts (TCs) was first proposed by Meyer and Land (2006) to describe "*the crucial aspects of a curriculum that are difficult for students to understand, but once they achieve understanding, a new window of understanding is opened on more knowledge*" (Land et al., 2016). Meyer and Land defined TC's as "*akin to a portal, opening up a new and previously inaccessible way of thinking about something"* (Meyer and Land, 2006). Threshold concepts are regarded as certain type of knowledge that students need to grasp before they can move their thinking forward (Land et al., 2006a). They are also considered as portals that lead to an irreversibly transformed way of understanding, learning or thinking thus enabling students to progress (Nicola-Richmond et al., 2018).

Threshold concepts in the teaching of neurophysiology could include the fundamental anatomical and functional properties of neurons and neural networks, the electrical and chemical signaling activities of the nervous system, and the neural regulation of physiological functions like cognition, sensation, and movement. Some of these concepts may be regarded as "threshold" because when students comprehends them, they can start to view the subject in a new light and start to draw links to other fields of study including neuroscience and neurobiology.

Based on my teaching experience, the learning of neurophysiology presents a pedagogical challenge and in most cases students wrestle cognitively and emotionally with threshold concepts in neurophysiology during the lectures. When students "wrestle cognitively and emotionally" with threshold concepts in neurophysiology during lectures, it means that they encounter significant intellectual and emotional struggles in understanding and grasping these complex concepts. These threshold concepts are pivotal in shaping students' understanding of neurophysiology, and their comprehension requires a fundamental shift in thinking. The cognitive wrestling refers to the mental effort, engagement, and cognitive processing required to grapple with these challenging concepts. On the other hand, the emotional wrestling implies the emotional investment, frustration, and potential feelings of uncertainty or confusion that students may experience as they navigate through these intricate ideas. According to Meyer and Land (2006), it usually takes considerable effort and time for students to grasp the troublesome knowledge and threshold concepts but as soon as they do, their understanding is irreversible and often unlikely to be forgotten (Meyer and Land, 2003). Meyer and Land (2006) proposed that the threshold concepts framework can be used as a way of understanding how students acquire mastery of difficult concepts. More often than not, TCs in neurophysiology transforms students' understanding both conceptually (in that they have the language and terminology to explain the different neurophysiology concepts) and ontologically (in that they start speaking like members of the discipline or community of practice such that the way they speak as individuals) (Moeller and Fawns, 2018).

Students who fail to understand troublesome knowledge and TCs in neurophysiology find it difficult to progress in their learning and often experience fragile knowledge building.

1.8.5.1 Characteristics of threshold concepts

In describing the threshold concepts, Meyer and Land (2003) used some five key distinguishing or identifying characteristics of TCs. Threshold concepts in any discipline tend to be *troublesome, transformative, integrative, irreversible* and *bounded* (Meyer and Land, 2003). Table 2 shows a summary of the descriptions of the identifying characteristics of TCs. Troublesome knowledge or the troublesomeness of knowledge has been used as a potential identifying criterion of TCs. However not all troublesome knowledge can be classified as TCs

(Hill, 2020). Although *troublesome nature* of TCs seem to be the main characteristic that defines them. Students demonstrate that they have grasped TCs by exhibiting an ontological and epistemological shift or *transformation* in their thinking (Nicola-Richmond et al., 2018). This shift exposes the previously hidden interrelatedness of disciplinary concepts, such that understanding these TCs results in an *irreversible* shift in students' perceptions of the subject that is "unlikely to be forgotten" (Yorke-Barber et al., 2008). The TCs are also described as *bounded*, meaning to say that they are specific to a particular discipline (Meyer and Land, 2006). Following the ongoing research into TCs, more characteristics such as *reconstitution*, *discourse* and *liminality* have been added to the key defining characteristics of TCs in order to differentiate TCs from key concepts (Baillie et al., 2013).

Table 1.2: The main characteristics of threshold concepts (Meyer and Land, 2003)

Characteristic	**Description**
Transformative	When students understand the threshold concept there is a shift in the student's perception of the area. The way a student thinks is altered through understanding the concept and involves becoming part of a discipline or community of practice.
Potentially troublesome	Troublesome knowledge is alien and often intellectually absurd at face value. Suggests that a concept is generally difficult for students to understand.

Potentially irreversible	Once students have learned the students are unlikely to forget the concepts
Often bounded	The concepts may form a boundary such that understanding these concepts may serve as a portal to open new areas of intellectual understanding. Also suggests that a concept is surrounded and bounded by other threshold concepts that may be related to the discipline.

As students learn TCs, they tend to occupy a 'liminal space' which has been described as a state where understanding of concepts by students is not authentic (Land et al., 2014). Liminality was also described as a period during which students shift or oscillate between previous and new understanding of the new concepts such that they have superficial understanding of concepts as they work towards genuine understanding (Moeller and Fawns, 2018). In other words, failure by students to pass through the *liminal space* will result in them being stuck, thus may fail to progress in terms of their understanding and learning of TCs (Nicola-Richmond et al., 2018). As students progress from the liminal space, they gradually acquire a deeper understanding of the TCs, become more engaged with the disciplinary concepts and learn to speak like experts as they assume their identity in the community of practice (Land et al., 2014). An understanding of why and how some concepts are troublesome or TCs plays a pivotal role in understanding how they are learned by students thus assisting the lecturers develop their curriculum, utilize teaching and assessment strategies that help move students out of the liminal space (Moeller and Fawns, 2018).

Due to the subjectivity and flexibility of interpretation of the characteristics of TCs proposed by Meyer and Land (2003), it is sometimes a challenge to identify TCs. Moreover, due to the personal nature of transformation experienced by students after encountering TCs, what one student may consider a TC may not be the same as the other students. Despite these shortcomings associated with the identification of TCs using the criteria method, the TC theoretical framework remains one of the potentially attractive approaches for curriculum development (Nicola-Richmond et al., 2018).

1.8.5.2 Models of threshold concepts

In an effort to identify TCs, two models have been proposed. The first model of identifying TCs is the Meyer and Land model which is also known as the *criteria model*. This model relies on the use of a set of defining criteria to identify TCs and based on the criteria model, a concept is identified as threshold if it is transformative, troublesome, bounded, integrative and possibly irreversible (Meyer and Land, 2006) as summarized in Table 2. In as much as Meyer and Land proposed these criteria for the identification of TCs, there is no suggested number of criteria that must be met in order for one to conclusively identify TCs. Rodger et al. (2015) seem to suggest that all five criteria of the Meyer and Land model must be met for conclusive identification of TCs. Other authors however believe that identification of TCs should be based on meeting some, but not all the criteria that were proposed by Meyer and Land (Park and Light, 2010). Meyer and Land (2006) however pointed out that "*Threshold concepts criteria cannot be described as an essentialist, definitive list of characteristics*".

The *concept model* that was proposed Davies and Mangan (2007) for identifying TCs is based on three different types of TCs namely basic, disciplinary and procedural. They suggest that procedural and disciplinary concepts are built on basic knowledge building such that they are regarded as TCs since they are considered as ways of thinking and practicing within a discipline (Davies and Mangan, 2007). This concept model is less commonly used when compared to the criteria model. However in medical education research some researchers use it to identify different types of concepts that exist in a discipline (Ross et al., 2010). Several, if not most, authors prefer to use the *troublesome nature* of a concept as a basis of identifying TC.

1.8.5.3 Differences between troublesome knowledge and threshold concepts

Since the introduction of the TC framework by Meyer and Land (2003), there has been a lot of interest from education scholars to use this framework in a wide range of disciplines such as medical education. The framework of TCs has been used to explore and explain how students understand or acquire expertise and become members of a community of practice in disciplines that are conceptually difficult such as Physiology (Moeller and Fawns, 2018). In one study by Horrigan (2018), they explored the role of laboratory classes in the identification of TCs by interviewing students and lecturers. The study showed that laboratory sessions play an important role in helping students grasp difficult concepts and overcome troublesome knowledge. In another study, Moeller and Fawns (2018) used the TCs framework to explore the potential barriers to the teaching and learning of complex skills such as the interpretation of electroencephalograms. They demonstrated the role of TCs and troublesome knowledge in determining expertise of medical trainees.

Threshold concepts are a useful way of understanding the transformation of medical students as they engage with troublesome ideas in medical education. A previous study by Hill (2020) in the training of healthcare professionals used the troublesomeness of TCs to explore the difficulties faced by medical students in the learning of prosthetics. The study involved interviewing both students and lecturers and utilised a phenomenographic approach to analyse data. It was shown that integration and transformation are essential for a concept to be considered a TC (Hill, 2020).

Threshold concepts have also been studied in nursing (Crookes et al., 2020), physiotherapy (Barradell and Peseta, 2018), clinical psychology education programmes (Laing et al., 2021) and occupational therapy (Fortune and Kennedy-Jones, 2014). In each of these studies it was shown that appropriately timed encounters with TCs by the medical students during their pre-clinical and clinical training resulted in their transition from '*one way of making meaning to another*' and once understood by students, students develop a qualitatively different view of the specialized knowledge. The pedagogical implications of the threshold concepts as a theoretical framework for research are that they are likely to give medical researchers and educators new perspectives to the "*barriers of effective learning*" (Neve et al., 2016) and provoke major shifts in educational practice (Sharples et al., 2016).

1.9 Problem statement

Over the 19 years that I have taught Physiology to several undergraduate medical and biomedical students, at three different institutions, I observed that there are some students that find it easy to understand neurophysiology when compared to the others. Upon reflection, it is evident that there are no major differences in the medical curriculum between South Africa and Zimbabwe. The challenges faced by students in both countries when it comes to learning neurophysiology are remarkably similar. The observed disparities in understanding and the factors influencing students' access to learning appear to transcend the differences in educational systems and resources. Therefore, addressing these challenges requires a unified approach that can benefit students in both South Africa and Zimbabwe.

While some students from the different educational institutions and countries can easily grasp neurophysiological concepts, others struggle and find some topics in neurophysiology as cognitively challenging and conceptually difficult. For the students that struggle to understand neurophysiological concepts, their knowledge-building process is fragile and they often fail to progress and seem to be ‘stuck’ thus find it difficult to integrate and associate the control of other systems by the nervous system. It is also commonly held that some students struggle with learning neurophysiology such that the learning of neurophysiology presents a pedagogical challenge (Krontiris-Litowitz, 2003). This variability on how students perceive neurophysiology, suggests that there may be factors that enhance or constrain epistemic access to learning neurophysiology.

The challenge for physiology educators is to identify these factors and address them to ensure that all students have equal opportunities to learn and apply neurophysiological knowledge in their future health science practice. There are studies that have been conducted using postgraduate students to investigate difficult physiology concepts in general, however none seem to have investigated the students’ perceptions of factors that enable or constrain the learning of neurophysiology. Exploring and understanding the students’ perceptions on what students identify as enabling or constraining the learning of neurophysiology could provide insights and a starting point for physiology lecturers in curriculum design, adoption of pedagogic tools and teaching strategies that facilitate the learning of neurophysiology and address the students’ challenges associated with these factors. The significance of this study lies in its potential to inform educational practice in the medical and biomedical fields. By describing the students' perceptions of factors that enhance or constrain epistemic access to neurophysiology learning, educators can design instructional interventions that support all students' learning needs. Ultimately, this research can improve students' understanding of neurophysiology, enhance their ability to integrate and associate the control of other physiological systems by the nervous system, and positively influence their future health science practice.

In summary, some undergraduate medical and biomedical students grasp neurophysiology easily while others struggle to understand neurophysiology, suggesting that that there are factors enhance or constrain epistemic access to the learning of neurophysiology. Students that struggle with neurophysiological concepts experience fragile knowledge building find it difficult to integrate and associate the control of other physiological systems by the nervous system. This negatively influences their ability to apply such neurophysiological knowledge in their future health science practice.

From the above problem statement, the following research question arise:

What do students perceive as the factors that enhance or hinder epistemic access to the learning of neurophysiology?

1.10 Research aim

The aim of the study is to explore and describe the biomedical students' perceptions of factors that enable or constrain learning of neurophysiology at a metropolitan university in South Africa.

1.11 Objectives

- To explore the perceptions of students on the factors that enhance epistemic access to and enable the learning of neurophysiology.
- To explore the perceptions of students on the factors that factors that hinder epistemic access to and constrain the learning of neurophysiology.

CHAPTER 2: METHODOLOGY

2.0 METHODOLOGY

2.1 Ethical considerations

Ethical considerations are moral values concerned with the degree to which the research procedures adhere to professional, legal and social obligation to the study participants and they aim to protect participants in research studies. I am aware of the research participant's right to privacy, and confidentiality. In conducting this research I took into consideration the ethical principles as set out in Dhai et al. (2011).

Ethical clearance for participant involvement in the proposed study was granted by the Human Research Ethics Committee (HREC) at the University of the Witwatersrand (Ethical clearance number: HRECNM19-09-084; **Appendix 2**) and the Research Ethics Committee (REC) at the University of Johannesburg, Faculty of Health Sciences (Ethical clearance number: REC01-75-2019; **Appendix 3**). This process included obtaining the permission from the University of the Witwatersrand (**Appendix 2A**) and the University of Johannesburg (**Appendix 3A**) registrars to conduct research with students at the respective institutions.

2.1.1 Informed consent and autonomy

Informed consent entails a process of information sharing and decision-making based on mutual respect and participation (Dhai et al., 2011). The participants who took part in this study were informed of the nature and methods of the study in a language they clearly understand. I secured informed consent (**Appendix 3C**) of all the participants after the purpose and details of the study were explained to the participants (**Appendix 3B**). Consent (**Appendix D**) was voluntary, informed and in writing for both the interview and the audio tape of the interview. The participants had the right to withdraw from the study at any time without fear of penalty or prejudice. The participant's information was kept in a password-protected drive by the researcher, while the had copies of the transcribed interviews were kept under lock and key.

2.1.2 Non–maleficence

The principle of non-maleficence is defined as the principle of avoiding harm or doing as little harm as possible (Dhai and McQuoid-Mason, 2011). I did not record any harmful effects from the study, but if the participant had felt that they needed any debriefing, I would have referred the participants for debriefing to a university registered counsellor. None such cases were reported among the participants recruited for this study. The participant's information and participation in the research was kept in confidence to ensure their privacy and autonomy. This was ensured by omitting any names of the participants from transcribed interviews. No information identifying the participants was used during data collection. Participants who consented (**Appendix 3C**) to take part in the study were assigned to a random number.

The only people that had access to the data without identifiers were the researcher, and the supervisor who was also the independent coder. The participant's participation were not anonymous, but data and the participation were kept confidential. The independent coder was also required to sign a confidentiality agreement.

2.1.3 Principle of justice

The principle of justice is an ethical obligation to treat each person in accordance with what is right and proper (Dhai et al., 2011). The researchers ensured that selection and recruitment, exclusion and inclusion of research participants was just and fair and based on sound and scientific ethical principles. The principle of justice was applied when participants were selected for this study and was based on experiences of the phenomenon.

2.1.4 Beneficence

Beneficence means doing good for others and promoting others interest and wellbeing (Dhai and McQuoid-Mason, 2011). Participating in this study may not confer direct benefits to the student participants. I acted in the best interest of the participants and promoted positive welfare by giving them a voice to express their perceptions factors enabling or constraining the learning of neurophysiology. I obtained permission to conduct the study from relevant authorities of the institutions that he used (Appendix 2A and 3A).

Confidentiality, beneficence, maleficence and privacy of participants were maintained as described below:

- The participants that took party in this study were be informed of the nature and methods of the study in a language that they clearly understand. They were asked to sign the consent form to be audio recorded as part of the study, if they agree (**Appendix 3D**)
- The participants were given the opportunity to withdraw from the study at any point during the study without any fear of penalty or prejudice (**Appendix 5**).
- No information identifying the participants was used during data collection. Participants who consented (**Appendix 3C**) to take part in the study were assigned to a random number on the data collection form, which were marked accordingly to ensure that data from the same participant was not recorded twice.
- Participants were asked to sign the consent form to be audio recorded as part of the study, if they agreed (**Appendix 3D**)
- I ensured that data was stored electronically in a password protected format as well as non-disclosure to any unauthorised individual. There were no known risks or benefits to participants in the present study.

- The data obtained will be stored for six years post completion of the study in a secure location after which it will be destroyed. However if the study is published, data will be stored for two years following the publication of data.
- The results of this study have been made available to the scientific community through oral presentations at one local and one international conferences.
- Participation in the interviews did not have any influence on the students' marks.
- The research was not anonymous however, the participant's involvement was kept confidential.

2.2 Research design and method

A qualitative descriptive study (Land et al., 2006b) was followed in order to explore the perceptions of students factors than enhance or constrain epistemic access in the learning neurophysiology. The use of a qualitative study design is justified in this context as it aims to explore students' perceptions of the factors that enhance or constrain their access to learning neurophysiology. The qualitative descriptive study design allows for a detailed description of the phenomenon, while semi-structured interviews capture participants' perspectives in their own words. Semi-structured interviews were conducted with a purposive sample of student participants (Meyer and Land, 2003). The researcher bracketed his experience in order to reduce possible bias. Bracketing the researcher's experience involves setting aside personal biases and preconceptions to approach the research with an open mind (Finlay 2009). It ensures that data collection and analysis focus on participants' perspectives, minimizing the influence of the researcher's own biases on the interpretation of findings. This practice promotes objectivity and unbiased exploration of the research topic.

2.3 Participant recruitment and sampling

The research participants were recruited from a cohort of first year Biomedical Science students studying physiology and neurophysiology in the Department of Human Anatomy and Physiology at the University of Johannesburg during 2020. All such students (N = 38) were invited to participate in the study. After gathering the students together, a colleague (or gatekeeper) explained the purpose of the research to the students before handing out and collecting the consent forms as well as the study information sheets. Students were asked to return a yellow slip (see **Appendix 8**) indicating their willingness to participate. This was done in order to prevent cohesion of the potentially vulnerable student population. The interviews were performed in the last week of the first semester after the students had done their lectures in neurophysiology

From this pool of volunteers, a purposive sampling technique was used to invite 10 students to participate in the study. Purposive sampling refers to the sampling method in which the researcher selects participants based on personal judgement about which ones are informative about the phenomenon being studied (Land et al., 2016). In this study, I purposefully selected undergraduate students studying Physiology since they had the knowledge to provide me with answers that I need in order for me to understand my research question on student perspectives in the learning of neurophysiology. In this study, each student's experience was valid and therefore saturation of "perceptions" was not expected. I followed the convention of Varpio et al. (2017) in this regard.

2.3.1 Inclusion criteria

First year undergraduate health sciences students in the Faculty of Health Science Department of Human Anatomy and Physiology at the University of Johannesburg.

Participants of any gender were included.

Participants were above the age of 18.

2.3.2 Exclusion criteria

Students repeating the module. Excluding repeating students from a study on the perceptions of neurophysiology learning helps minimize biases that may arise due to their familiarity, prior experience, motivation, and attitudes. By focusing on students encountering the subject for the first time, researchers can gain more accurate insights into their genuine perceptions and experiences.

2.4 Data collection and the interview process

Qualitative data was collected using face-to-face semi-structured interviews (using open-ended questions in **Appendix 4**) using a standardised interview transcript. A total of 10 first year undergraduate students who were registered for the Physiology module with the Department of Human Anatomy and Physiology and studied neurophysiology in the first semester were interviewed. I conducted the interviews in English, as this is the language of education at the University of Johannesburg. There were no ethical or cohesion issues since the students participating had completed the module and content that the researcher taught the students, neither was the researcher involved in setting or marking their assessments as the examination on this module had been completed at the end of term 2.

During the face-to-face interviews with the students, the questions asked focused on the students' perceptions of the areas of neurophysiology that are fundamental to the grasping the topics that are troublesome to the undergraduate students. The students were met individually in my office and asked if there were any specific theoretical concepts in neurophysiology that stood out for them as being particularly difficult to understand. If they suggest particular concepts, they were asked if they managed to overcome the difficult. If they responded that they managed to understand the concepts then they were asked to explain how they eventually managed to grasp the concept. If they respond that they had failed to understand the concept, they were asked for their perspective and opinions on why they think that they failed to understand the concept, students were also asked to explain if they felt there was anything that could have been done differently to help them grasp the cognitively challenging concept. The main goal was to get an understanding of the concepts that students regarded as threshold concepts and their perceptions of these concepts.

The interviews were audio recorded with the permission of the participants (see **Appendix 3D**) to ensure the accuracy of the collected data. Some of the principles and procedures used during the interview process were described by Doody and Noonan (2013) and Webb (2015). The date, venue and time was determined by the availability of the participants and the privacy of the facility to ensure confidentiality of responses. Each interview sessions was approximately 10-20 minutes. I started each interview session with a brief explanation of the purpose of the interview. I used an interview technique that clarified, probed, paraphrased and summarised the responses of the participants. All the hesitations, false starts, cut-offs in speed of speech, the interviewee's guggles (e.g. *ummm, ahh, tjoh*) laughter and long pauses were recorded. The collected data was treated collectively in order to qualitatively analyse differences in perceptions across the whole sample instead of characteristics of individual responses from interviewees (Fyrenius et al., 2007a).

2.5 Data management

I transcribed the audio-recorded interviews to reproduce all spoken words and sounds. The ideas were approached with openness to whatever meanings that emerged from the data. During the transcription of data, no names were revealed and the audio-recorded data was stored in a password protected file which was only be accessed by me and the supervisor who was also the independent coder to ensure confidentiality. I edited the interview transcripts for brevity by removing any words or phrases that were not essential for understanding the overall meaning of the transcript.

2.6 Data analysis

In identifying and engaging with thematic analysis, the researcher utilised a general thematic analysis approach described by Braun and Clarke (2006) to interpret and conceptualise findings. The approach involves the following steps:

2.6.1 Familiarisation of the researcher with data

The interview scripts were read individually and repeatedly to enable familiarisation with data. This step entailed "*repeated and active*" reading of the interview scripts in order to familiarise with the entire set of the data (Braun and Clarke, 2006). The researcher transcribed all the audio recordings by himself, which gave him the opportunity to check the accuracy of the data and engage with all the data.

2.6.2 Generation of codes

A software programme and a data management tool MAXQDA (version 2018.1) was used to establish a coding framework and assign codes to recurring themes in the 10 transcribed interviews. After the coding of the first two interview transcripts, a preliminary analysis was performed and the approach was refined. The coding process was done iteratively thereafter, which involved the analysis of 2-3 transcripts at a time. The researcher made some notes and observations that were interesting to the research question. Using a deductive approach, the researcher identified pertinent issues that were raised by the data alone and defined the codes such that there was no overlap with other codes. At each stage of interview transcript coding, the coding framework was adjusted as required and where necessary new codes were added, reviewed or re-arranged with constant reference to the key elements or characteristics of threshold concepts (see Table 1). Coding of the interview transcripts was done with the aid of researcher field notes, which included information about the unstructured observations made during interviews and interpretation of these observations. The researcher worked with the supervisor who independently coded the data. Consensus in codes and categories was achieved through negotiation and discussion in order to improve the credibility of the findings. At each stage of data analysis, the coding framework was modified as required and as necessary.

2.6.3 Searching for themes

Following the assignment of codes, significant statements and phrases that pertain to the perceptions of students on their learning of neurophysiology were extracted, meaningfully assigned and organised into clusters of themes. The emerging themes were compared across transcripts, refined and their connections explored. Searching for themes was an "*active and* *interpretive*" process that was based on the examination of the coded data. The researcher analysed and combined the codes that were related to one another using an inductive approach to ensure that the data was linked to the original data set (Maguire and Delahunt, 2017). The frequency of occurrence and variation within the identified themes were considered.

2.6.4 Reviewing of themes

Following the identification of themes, the researcher went on to review the themes by ensuring that the coded data placed in each of the identified themes fitted properly into the identified themes. The emergent themes were also compared to the criteria model as proposed by Meyer and Land (2003) and shown in Table 2. In order to achieve this, the researcher went on to check if the data from the interview transcripts had aspects in common or coherent. Some themes during this stage of data analysis were either rearranged, combined or discarded altogether. Using MAXQDA, the researcher kept some notes and memos especially on how the themes were developed. In instances where the researcher felt the coded data did not fit into certain themes, he revised the codes as recommended by (Clarke and Braun, 2014).

2.6.5 Defining and renaming of themes

In this stage of data analysis, the researcher created the definitions and descriptions of each of the identified themes in the previous step and linked them to the research question of students' perceptions of the threshold concepts in the learning of neurophysiology.

2.6.6 Production of the manuscript

The last part of data analysis involved the production of the manuscript by describing key findings in the results (Chapter 3) and discussion (Chapter 4) sections respectively. Measures to ensure trustworthiness of the data are described in **Appendix 8.**

2.7 Measures to ensure trustworthiness

Trustworthiness of the study was established following the criteria outlined by Guba and Lincoln (1994), Connelly (2016) and Nowell et al. (2017). These criteria include credibility, dependability, confirmability, and transferability.

2.7.1 Credibility

Is the degree to which the researcher showed truthfulness of the research findings (Yorke-Barber et al., 2008, Nowell et al., 2017). It also refers to the confidence in the truth of the data and their interpretations as well as carrying out a study in a way that enhances credibility of the findings (Guba and Lincoln, 1994). In this study, credibility was ensured through prolonged engagement in the interview and participant checking. Field notes were taken to improve credibility in assigning meanings. A consensus meeting and discussion was convened with the supervisor (also the independent co-coder) to:

a) achieve consensus in the data analysis and enhance credibility of the study and

b) to finalize the themes and categories took place to ensure that findings are credible.

My prolonged engagement with the data enabled me to gain insight into the phenomenon, and to have an in-depth understanding of the students' perceptions on the learning of neurophysiology under study.

2.7.2 Dependability

It is the evidence of the consistency of research findings. It also refers to the stability of data overtime and under different conditions if the study was to be repeated with the same participants in the same context (Guba and Lincoln, 1994). Credibility cannot be obtained in the absence of dependability. Dense description of the research methodology was done by a thorough rich description of the research setting (Guba and Lincoln, 1994). I ensured dependability by providing an audit trail. This was ensured by providing a thick description of the research method and design including ethical considerations.

2.7.3 Confirmability

Is concerned with establishing that the data and interpretation of the findings were not influenced by prior experience, but rather a representation of the information participants provided. It also refers to objectivity that is the potential for congruence between two or more independent people about the data accuracy, relevance or meaning (Nowell et al., 2017). Bracketing, the technique of acknowledging the prior experience of the researchers in the field and documenting this in a reflective way in order to reduce the researchers' bias in interpreting the statements of the participants was used to make sure the findings represent the voices of the participants. My first concern was to ascertain if findings were grounded in the data, a matter easily determined if appropriate audit trail linkages have been established. Findings reflects the participant's voice, supported by direct quotes and field notes and not the researcher's biases, motivations or perceptions (Guba and Lincoln, 1994, Nowell et al., 2017).The findings were followed with verbatim quotations and field notes from the interviews. Raw data has been kept for inquiry audit (Guba and Lincoln, 1994).

2.7.4 Transferability

The degree to which research findings can be transferred to other settings or groups. Transferability was ensured through providing enough descriptive data necessary to enable a prospective researcher who may be interested in the same type of study to replicate this study in other settings. I described the research methodology and sampling in detail. The researcher also provided a thick description of the findings including direct quotes and the findings were re-contextualised in the literature through literature control.

2.8 Researcher positionality

2.8.1 Teaching experience and personal philosophy on teaching and learning

I am a mid-career, pre-clinical medical and basic medical science researcher based at the University of Pretoria where I am employed as an Associate Professor in the Department of Physiology, at the University of Pretoria. I am a BSc Hons graduate from the University of Zimbabwe and later joined the University of the Witwatersrand, School of Physiology where I studied for and graduated with an MSc Medicine (Physiology) and a Doctoral degree (Ph.D) in Medical Physiology. I also hold a Postgraduate Diploma in Health Sciences Education and am currently finalising my Master of Health Science Education studies from Wits University, Centre for Health Science Education.

My teaching philosophy is based on the constructive learning theory and constructive alignment. I believe that students construct their own knowledge and understanding through an active, collaborative, and reflective learning process. My role as an educator is to facilitate this process by creating a supportive and challenging learning environment that encourages students to engage in critical thinking, problem-solving, and inquiry-based learning.

I have 19 years of experience teaching medical physiology to undergraduate and postgraduate students at four different universities, and during this time, I have developed a deep understanding of the factors that enable and constrain the learning of physiology and neurophysiology. I am particularly interested in exploring troublesome knowledge and threshold concepts and how these can be overcome by using active learning strategies, including problem-based learning, case-based learning, and collaborative learning.

I believe that practical skills and the application of physiology are essential to students' learning, and I incorporate a variety of teaching technologies, such as simulations, virtual labs, and interactive multimedia, to engage students in hands-on learning experiences. I also use a range of assessment criteria to provide feedback to students and to evaluate their learning outcomes, including formative and summative assessments, peer evaluations, and self-assessments.

My teaching approach is based on constructive alignment, which means that my learning outcomes, teaching strategies, and assessment criteria are aligned to ensure that students are actively engaged in their learning and are able to apply their knowledge and skills to real-world situations. I believe that this approach helps students to develop critical thinking skills, problem-solving skills, and the ability to work collaboratively with others.

Overall, my teaching philosophy is centred on creating a learning environment that supports students' active engagement in their own learning, fosters their intellectual curiosity, and prepares them for their future careers as medical professionals.

2.8.2 Researcher positionality on the student participants

The research participants were recruited from a cohort of first year Biomedical Science students studying physiology and neurophysiology. I confirm that I taught neurophysiology to the students that participated in the current study. The interviews were performed in the last week of the first semester after I had taught and assessed them on neurophysiology concepts. As a result I acknowledge that there may be potential for bias or influence in the interpretation of findings from this study. It is possible that my previous teaching role may have established a power dynamic with the students, which could have affected the students' responses during the interview. The students may have felt obliged to provide answers that align with my expectations, or they could have felt hesitant to provide negative feedback due to the power differential.

Furthermore, my prior knowledge of the students and their abilities could have potentially affected the data analysis process. In particular I could potentially have preconceived notions about the students' strengths and weaknesses and their perceptions of factors enhancing or constraining the learning of neurophysiology, which could have biased my interpretation of the interview data.

To mitigate for the potential biases, I took steps during the participant recruitment process to prevent cohesion of the potentially vulnerable student population as described in section 2.3. During interviews, students were informed that they could withdraw at any time without prejudice and a free and relaxed environment was provided in order to minimize the power differential during the interview. Additionally, I also reflected on my potential biases during data analysis and sought out the perspectives of my supervisor to ensure a more objective interpretation of the data.

2.8.3 Teaching methods used in teaching neurophysiology

I teach Physiology using a systemic approach where different Physiology systems (e.g. endocrine, renal, cardiovascular systems to name but a few) are taught at different times or levels according to learning outcomes and objectives as prescribed by the relevant department.

When teaching neurophysiology to the class from which the participants of this study were recruited, I made use of an blended teaching approach with and outcomes-based curriculum (Jansen, 1998) as part of my teaching practice. Neurophysiology was taught over two weeks.

The blended teaching approach involved combining traditional face-to-face teaching with online learning activities. This approach was aimed at enhancing students' learning experiences and outcomes by leveraging the benefits of both face-to-face lectures and online learning. In some instances I used a flipped classroom strategy where I introduced to the content through online materials and worksheets before students attend the face-to-face class. This gave them the opportunity to learn at their own pace, and the face-to-face classes were used for interactive activities, such as group discussions and problem-solving exercises. Using this approach students took ownership of their learning and actively engaged with the course content.

2.8.4 Assessment methods

Understanding physiological concepts demand the use of entirely different parts of the brain than language and thus must be assessed in multiple non-verbal ways. For this reason, I made use of a number of authentic formative and summative problem-solving tasks as well as numerous assessment options to accurately assess and evaluate module content for this group of students involved in the current study. To this end I have used computer-based assessment methods which I modified from the departmental guidelines such as traditional tests or exams and alternative types of assessment tasks *viz* presentations, oral tests, quizzes and practical assessments. I also made use of a wide range of assessment tasks which allowed me to fairly and accurately assess the students' learning ability.

2.8.5 Resources and learning activities

I used online tools such as a learning management system (Blackboard) for discussion forums and interactive simulations or videos to supplement the face-to-face teaching. Discussion forums encouraged peer-to-peer learning and collaboration, while interactive simulations or videos provided students with opportunities to visualize and understand neurophysiological processes. The learning management system was also used to provide students with additional resources such:

a) PowerPoint lecture slides that were uploaded onto the learning management system (Blackboard).
b) Animations and some YouTube videos highlighting certain key concepts.
c) Recommended Physiology textbooks that the students could access via the library portal
d) Worksheets with applied extra practice questions that students had to study before and after the lectures
e) Practical sessions - I also made use of a number of practical sessions that usually run concurrently with the lectures in order to foster enquiry-based learning (Casotti et al., 2008). The practical aspect of this module in Human Anatomy and Physiology for the class provides an opportunity for students to perform measurements and interpret data obtained from some routine techniques employed in diagnosis and management of pathophysiological conditions.

CHAPTER 3: FINDINGS

3.0 Findings

3.1 General characteristics of the participants that were interviewed

A total of 38 students were invited to participate in this study through the recruitment process described in section 2.3. There were 10 students that gave their permission to be interviewed. More female (n = 8) than male (n = 2) students were among the students that were interviewed. The selected characteristics of the participants are displayed in Table 3.1.

Table 3.1: Selected characteristics of the students who were interviewed

Partipant ID	Gender	Age	Mark/Grade achieved
1	F	20	Pass
2	F	20	Pass
3	F	21	*Fail
4	F	20	Pass
5	F	20	Pass
6	M	21	Pass
7	F	21	Pass
8	F	21	Pass
9	M	20	Pass
10	F	21	*Fail

*Students who failed the neurophysiology at the time of the study main assessment but still managed to progress based on a good average mark.

3.2 Students' perceptions on the factors enabling the learning of neurophysiology

Table 3.2 summarises the factors that were identified by the students as enabling the learning of neurophysiology.

3.2.1 Prior learning of biological science concepts in high school

The findings of the current study suggest that students considered their prior learning experiences to be an essential factor in their ability to learn neurophysiology. Participants consistently reported that their prior knowledge and skills helped them understand complex concepts in neurophysiology and facilitated the learning process. Moreover, participants noted that their previous exposure to related topics and experiences helped them develop a deeper understanding of neurophysiology.

Most of this prior learning of biological concepts was from their high school Life Sciences subject, which is also a pre-requisite for students enrolling to study health sciences degree programs in the Faculty of Health Science at the University of Johannesburg. The role of prior educational experience was also highlighted in the understanding certain concepts such as action potentials.

"I also remembered some of the stuff on impulses that we did when I was in first year and in matric like in high school and it helped me a lot although you went deeper in this section than what we did in matric…" (Participant 1).

One student mentioned the role of prior knowledge from matric and first year Biology classes respectively helped them to understand the concept of action potential generation and propagation.

Table 3.2: Factors enabling the learning of neurophysiology

Enabling factor	**Reason**
Prior learning of biological concepts in high school	Building onto the foundational knowledge in Life Sciences from high school
Resources	Easy access to learning material such as lecture notes and videos on the Blackboard learning management system
Practical sessions	Reinforcement of theoretical knowledge with practical aspects in the learning of neurophysiology

"… I must say that some of the lessons that we learnt when I was in the Biology class like helped me understand some of these neuro lectures like the impulses…." (Participant 7).

3.2.1 Resources provided as enabling learning of neurophysiology

The findings of this study suggest that participants perceived the availability of learning materials and resources as a critical factor in their ability to learn neurophysiology. Participants reported that prescribed textbooks, lecture notes, and online videos were readily accessible and provided valuable information that facilitated their learning process. Participants emphasized the importance of having multiple resources to draw from and the ability to revisit materials when needed. These findings highlight the significance of providing comprehensive learning resources and support to learners when designing neurophysiology courses or programs. One participant had this to say about the resources used *"So yes I used the textbook and thane also wrote some side notes, so I used to write down and it made it easy to understand." (Participant 6).*

Most importantly, the students used provided links to access YouTube videos for studying and improving their epistemic access of neurophysiology. *"So mostly it was due to educational videos that I found on YouTube that actually were brief but explained it to a point where you could understand that this nerve does that and that. So it was easier to understand with educational videos" (Participant 4).*

3.2.2 Practical laboratory sessions

Several participants in the study mentioned the importance of practical sessions in their learning of neurophysiology. In particular, some students recognized and valued the role that these sessions played in enhancing their understanding of the subject matter. For instance, one participant noted that *"I also learned a lot during practicals which were nice in that they gave us* *an opportunity to apply what we had been taught in lectures" (Participant 10)*. Another participant echoed this sentiment, stating that *"doing the experiments myself helped me to grasp the concepts more fully than just reading about them in a textbook." (Participant 5)*. These comments suggest that practical sessions were perceived as a valuable supplement to traditional classroom learning for some students in the study.

3.3 Neurophysiology as a challenging discipline

When asked about their experience with learning neurophysiology, participants in the study shared a range of perspectives. Some described finding the subject relatively easy compared to other physiological systems they had studied. For example, one participant remarked that *"Well I found neurophysiology as a great topic especially towards the body, I mean its like, I feel like it controls, it's a basic or you know control centre of the body, you know and when it comes to the functioning movement of systems, so basically it is quite an interesting topic and I would definitely like to know more" (Participant 2).* Another participant echoed this sentiment, stating that *"I didn't really have any problems with neurophysiology. It just made sense to me." (Participant 8).*

However, not all participants shared this view. Some described finding neurophysiology challenging, or at least more difficult than other areas of physiology. One participant explained that *"Neurophysiology was kinda difficult to understand compared to the other systems that we did like the respiratory system and reproductive system and the digestive system for example is things that are related to I would say for example the digestive system, you know that you swallow and all the processes related to swallowing. In neurophysiology, you are just not able to* *relate, like how can I put this? ……... I so I think neurophysiology was a lot challenging compared to other systems." (Participant 3).*

Another participant similarly noted that neurophysiology was a cognitively challenging area that was difficult for them to understand *"To be honest neurophysiology was one of the hardest chapters that we actually delt with throughout the year, not just because of the information or the content that it had, I think that's what made it a little bit more difficult than the other areas" (Participant 4).* Another participant echoed this statement by saying that "*"Neurophysiology compared to other systems, its difficult tjoh according to me, it's too complicated it's too hard" (Participant 7).*

Responses from some of the students suggests that the nature of the neurophysiology knowledge made it difficult to learn neurophysiology and one student had this to say *"To be honest neurophysiology was one of the hardest chapters that we actually delt with throughout the year, not just because of the information or the content that it had, I think that's what made it a little bit more difficult than the other areas" (Participant 4).* While another one said *"Honestly I found that it was more difficult to understand the neurophysiology part but then these other systems it wasn't that like, how can I say it, it wasn't that difficult to grasp you know and these areas like the notes were detailed. It was kind of difficult for me to grasp at the end I understood." (Participant 6).*

In summary these diverse perspectives suggest that participants varied in their experiences with learning neurophysiology, with some finding it relatively easy and others encountering more difficulty.

3.4 Students' perceptions of factors constraining the learning of neurophysiology

Table 3.3 is a summary of the factors that were identified as constraining to their learning of neurophysiology. Constraining factors make the learning of neurophysiology troublesome and limit epistemic access to Physiology knowledge.

3.4.1 The quantity of work as a constraining factor in the learning of neurophysiology

Many participants in the study highlighted the amount of material they were expected to cover within a relatively short timeframe as a major challenge in learning neurophysiology. Specifically, several participants noted that the sheer volume of information related to the special senses - such as hearing, smell, vision, and balance - made it difficult to keep up with the pace of the course.

For example, one participant explained that *"There was too much to study especially all those special senses. Imagine from the ear, the sense of smell and all the balance and the vision system" (Participant 6)*. Another participant echoed this sentiment, stating that *"It was interesting but I didn't like the special senses, it was too much information, too much to study there and most of the parts I didn't get because I felt like everything was just moving too fast. Ok for me personally…" (Participant 9)*.

The pressure of having to learn a large amount of material in a short amount of time appeared to have negative consequences for some participants' cognitive functioning. Despite these challenges, some participants expressed a belief that they could have grasped the concepts if they

Table 3.3: Factors constraining the learning of neurophysiology

Constraining factor	**Reason**
Amount of work to be covered	Cognitive overload and defective/impaired knowledge building
Language and terminology	The use of difficult terminology, which makes it a challenge to understand certain concepts
Pre-requisite knowledge such as Chemistry and Physics	The need to understand challenging basic science modules for application in neurophysiology
Existence of troublesome knowledge and potential threshold concepts	Knowledge that challenged the students resulting in cognitive conflict

had had more time to study. However, the pressures of time and exams meant that they had to rush through the material, which limited their ability to fully understand and retain the information *“Anyway I feel I could have if I had enough time but then I just brushed through because not enough time and exams” (Participant 1)*.

3.4.2 Terminology and language as a constraining factor in the learning of neurophysiology

Using thematic analysis it emerged that many participants identified the terminology and language used in the neurophysiology as a significant challenge to their learning. This was attributed to the fact that neurophysiology has a unique vocabulary that includes many technical terms that are not necessarily used in other areas of physiology. As one participant noted, *“I think for me the other problem is that there are so many new words which mean different things and are used in many different ways” (Participant 5)*.

The use of technical language was seen as a particular challenge for participants who did not have a prior background in neurophysiology. As one participant explained, *“There was too much anatomy and physiology jargon used in this section, and uhhhh, these were English terms that had a different meanings” (Participant 3)*

Overall, the findings suggest that the technical vocabulary and terminology used in neurophysiology was a significant barrier to learning neurophysiology for many students, particularly those without prior experience in the field.

3.4.3 Pre-requisite knowledge of physical sciences as a constraining factor in the learning of neurophysiology

Many participants in the study noted that the learning of certain concepts in neurophysiology required a clear understanding of concepts in physical sciences such as chemistry and physics. However, several participants reported challenges in understanding these subjects, which they identified as a constraining factor in their ability to learn certain neurophysiology concepts. As one participant explained, *"I struggled with some of the concepts in neurophysiology that relied heavily on physics, like the generation and propagation of action potentials. I didn't have a strong background in physics, and that made it difficult to grasp some of the more complex ideas." Participant 9.* Another participant echoed this sentiment, stating that *"I have always struggled with Physics and Chemistry courses and I was surprised to see that we still have to remember these things in physiology tjoh aaii sir no" (Participant 4).*

The need for a strong foundation in physical sciences as a prerequisite for understanding certain concepts in neurophysiology was a common theme among the participants. Many felt that their lack of knowledge in these areas was a significant obstacle to their learning. As one participant explained, *"I think if I had a better understanding of the concepts in physics and chemistry, I would have been able to understand neurophysiology better. But because I didn't, it felt like there were just too many gaps in my knowledge." Participant 7.*

These findings suggest that a clear understanding of physical sciences such as Chemistry and Physics may be a prerequisite for understanding certain concepts in neurophysiology. However, challenges in understanding these subjects may serve as a constraining factor for some students.

3.5 Existence of troublesome knowledge and threshold concepts as constraining factors on the learning of neurophysiology

From the data, students identified several topics that were demonstrative of conceptual difficulties that they encountered in the learning of neurophysiology. Thematic analysis of participants' responses to the interview questions showed that the sensory and motor nerve (somatic ascending and descending) pathways, the functions of different regions of the brain, and special senses emerged as troublesome knowledge that limited epistemic access of neurophysiology knowledge.

3.5.1 Somatosensory and somatomotor pathways as troublesome knowledge limiting epistemic access

Participants in the study reported that they found the different somatosensory and somatomotor pathways that send sensory information to the brain and motor commands from the brain, respectively, to be troublesome and difficult to understand. These pathways were viewed as crucial for providing an understanding of the clinical context and pathogenesis of neurological deficits associated with somatosensory information and the transmission of motor commands to the effector organs. As one participant explained, *"... there are several types of the somatic tracts to the brain and it makes it tough to know all them and the type of sensory information that they carry" (Participant 7)*.

In addition to the action potentials, students must understand how sensory information is send to the central nervous system and motor information from the central nervous system to the peripheral effectors. This knowledge forms the basis of understanding how the human body interacts with the environment. Some students went on to describe how motor and sensory pathways impacted their understanding of other areas of neurophysiology such as the general senses.

"I found out that what we learnt in neurophysiology especially the impulse, neuronal paths and the neurons was actually important for the other systems, because we could see like in the digestive system that how the CNS participated in that and you were like ok, I know this, so it was easier to understand the other systems with your knowledge of the neurophysiology" (Participant *4).*

These findings suggest that the somatosensory and somatomotor pathways are viewed as complex and difficult to understand by students studying neurophysiology. However, these pathways are also seen as essential for understanding the clinical context and pathogenesis of neurological deficits associated with somatosensory information and the transmission of motor commands to the effector organs.

3.5.2 Brain regions and their functions as troublesome knowledge limiting epistemic access in the learning of neurophysiology

Several students who participated in the study identified the topic of brain regions and their functions as a troublesome area in their learning of neurophysiology. Specifically, some participants mentioned that understanding the functions of different brain regions was a challenge for them. One participant stated, *"The brain, its a very complex structure because as a person you think that you know a lot about the brain and how its functioning, they tell you about two parts of it, the right and left side, there is more to it, we don't even know the depth of the brain and functioning of everything, I think I should take time on it" (Participant 2)*

Another participant added, *"The brain regions were definitely a challenge for me. I found it hard to remember all the different regions and what they do." Participant 10*.

Although previous and contextualised experience from the Life Science subject in matric enabled some level of integration of knowledge, some students still identified this area of neurophysiology as difficult to understand, with others pointing to specific aspects of the brain function as more difficult after a probing question (*Is there anything in particular about the brain, something that you can think of?*) on what was particularly difficult about the brain was asked, the participant had this to say:*"Ok I think of the hypothalamus, the pituitary gland it's the interior parts pf the three lobes everything thats where I got confused" (Participant 2)"*.

The understanding of the different regions of the brain was thought to be troublesome in two different ways; either as tacit or conceptually difficult. A fundamental understanding of the functions of the different regions of the brain is necessary for understanding the integratory role of the brain and its control of other systems. It is also important in the students' acquisition of knowledge and skills as well as clinical significance and the role of the brain. As alluded to by some of the students *"I would say of the topics that we covered the brain was the most difficult, all those areas and the lobes and what they eisssh yah it was difficult" (Participant 1)*. Similarly another student had this to say *"Also I think the brain was not easy as there are many parts of the brain that perform many functions, knowing all that was not easy" (Participant 4).*

Key to the central nervous system function is a holistic understanding of the different regions of the brain. Understanding this area that was identified by students as difficult requires the integration of knowledge about the location of the five lobes of the cerebral hemispheres which in turn will allow their progression to a holistic approach where students link the individual functions of the areas of the brain to the rest of the brain and the central nervous system components. One student identified the regions of the brain as difficult to understand due to the amount of content to be covered which support their identification of the amount of work to be covered as a factor limiting their understanding of neurophysiology: *"umm I don't know maybe there was too much to do… and also it was difficult to remember which part* (of the brain) *performs which function" (Participant 1)*.

3.5.3 Special senses as troublesome knowledge limiting epistemic access in the learning of neurophysiology

Participants expressed that special senses were troublesome knowledge and presented a challenge for them to comprehend. Special senses refer to sensory modalities that possess specialized receptors with a unique structure that is restricted to specific parts of the body. The five special senses identified are smell (olfaction), taste (gustation), vision, hearing (audition), and balance (equilibrium). The primary function of special sensory receptors is to detect environmental stimuli and convert their energy into action potentials, which are then transmitted to the brain and spinal cord for integration and processing. Despite this, students reported facing difficulties in studying special senses due to limited time and complexity. As one participant said *"There was too much to study especially all those special senses. Imagine from the ear, the sense of smell and all the balance and the vision system" (Participant 6),* while another participant mentioned that *"The special senses and the impulses, I didn't understand the thing about special senses, but others the hormonal control, I think that one is very interesting for me." (Participant 7).*

Students may have failed to understand that it is not the quantity of work to be covered that makes special senses difficult to learn but rather their troublesome nature. *"Yah those special* *senses had so much to cover it was difficult to do all of that stuff in one term, maybe we should do them separately in term 3" (Participant 4).* Although students did not explicitly state that excessive work to be covered hindered their progress in understanding special senses, it may be possible that cognitive overload was a troublesome to their learning of neurophysiology.

3.5.4 The generation of action potentials as a troublesome knowledge and potential threshold concepts that constrained the learning of neurophysiology

In this section of the results, the finding of the study regarding students' perception of the generation and propagation of action potentials is presented. Participants indicated that this concept was troublesome knowledge and a potential threshold concept that acted as a significant barrier to their learning of neurophysiology. As a result, they had a superficial and incomplete understanding of the generation and propagation of action potentials. *"This thing of impulses and how they start from resting potential to threshold and all those channels were a challenge for me to understand. Most of the words were like tough to umm understand" (Participant 3)*

Action potentials refer to the electrical signals that are transmitted along the neurons to facilitate communication between different parts of the body. The students' experience highlights the importance of addressing threshold concepts in neurophysiology education to enhance students' comprehension and facilitate meaningful learning.

The findings also revealed that some students had difficulty comprehending this concept, resulting in cramming without a complete understanding of the subject matter as mentioned by one participant *"…Tjoh sir the nerve action impulses were a challenge to know, I read over and over and still had issues understanding this. I eventually had to cram so that I could just pass" (Participant 5).* Action potentials refer to the rapid and transient reversal of electrical potential across the plasma membrane of excitable cells, such as neurons and muscles, triggered by a stimulus. The understanding of the generation of action potentials is a crucial knowledge base in neurophysiology, as it facilitates the comprehension of the communication between neurons transmitting sensory information from receptors to the central nervous system for integration and processing. The participants' experience highlights the need for effective teaching methods to enhance students' understanding of this important area in neurophysiology to prevent superficial learning and improve student performance.

3.6 Approaches used to achieve understanding and overcoming constraining factors

In this section of the results, the finding of the study regarding the approaches and resources used by participants to overcome constraints in their learning of neurophysiology is presented. The theme on strategies and resources utilised by students to overcome the cognitively challenging concepts was neither troublesome knowledge nor a threshold concept. I was compelled to include this data as I believe that resources and strategies used by students play an important role in dealing with factors that constrain their learning of neurophysiology.

3.6.1 Use of recommended and provided resources

The study shows that participants utilised a variety of resources to deal with factors that enhance and constrain the learning of neurophysiology. In response to the question "*how did you overcome the challenges associated with difficult concepts?*", students highlighted that they utilised the provided resources (notes and recommended textbooks) and other online resources: *"Generally when it comes to studying, I take time to look at the notes, and if I don't understand something in relation to the notes, I research about it, because its interlinked right, so if you don't get this part and you search for it on the internet then it makes all the concepts come* *together. I research and study and try to understand first before saying.. so studying is basically taking time to understand what's happening, that's how I overcame" (Participant 2)*. Another participant echoed the same sentiment and stated that *"So yes I used the textbook and then also wrote some side notes, so I used to write down and it made it easy to understand." (Participant 6).*

The utilisation of a range of resources indicates that students proactively seek alternative approaches to overcome learning barriers, highlighting the importance of diverse and accessible resources in neurophysiology education. These findings emphasise the significance of ensuring students have access to a variety of resources to enhance their comprehension of threshold concepts in neurophysiology.

3.6.2 Utilisation of YouTube videos

The findings also show that YouTube videos were an essential resource for participants to comprehend difficult concepts in neurophysiology *"So mostly it was due to educational videos that I found on YouTube that actually were brief but explained it to a point where you could understand that this nerve does that and that. So it was easier to understand with educational videos" (Participant 4).* Participants reported that these videos helped them to overcome factors that limit epistemic access to information and facilitated their understanding of the subject matter as one participant mentioned that *"I just used the YouTube channels for anything that I did not understand , I just went to search ok how what is happening if this is not happening and this is supposed to happen now, I just went to YouTube videos or even though I don't trust google information because anyone can just post anything , inaccurate like he/she can just post what he/she thinks is correct but which is not medically correct or somehow proven that this is legit or* *this is exactly what is happening so I decided to compare the YouTube channels ok what is happening in this channel, like is it the same or similar to what the next YouTube channel will say to me and is this the same…" (Participant 8)*. This sentiment was echoed by another participant who stated that *"There a program called the Khan Academy on YouTube. Its quite nice, they have everything there and then also I would just search on YouTube, but I prefer to use the Khan Academy there they explain it in simpler terms and when they explain, they actually write and maybe when they draw something, you actually listening and also viewing the structures and whatever that they are drawing so the Khan Academy actually helped me a lot and my friend also. We also communicated with my friend via WhatsApp, if I had a question I would just drop a message" (Participant 9).*

The utilisation of YouTube videos as a resource highlights the importance of technology and multimedia resources in enhancing students' comprehension and engagement in neurophysiology education. These findings emphasise the significance of integrating multimedia resources such as YouTube videos in neurophysiology education to improve students' access to information and facilitate their understanding of challenging concepts.

3.6.3 Repetition of work and diagrams

Participants highlighted the use of repetition as a coping mechanism to reinforce their understanding of complex concepts as stated by one participant *"I guess just repeating, repeating whatever that I was doing at the time um just repetition, that's what I did to help me or assist me to pass in everything that I was doing at the time" (Participant 8)*. Some participants employed unique methods such as the use of diagrams and 3D models to visualise and comprehend the material: *"Yah exactly, I would use 3D diagrams on imagining what's happening now ok for* *example contraction, like what happening now, the calcium ions to the contracting muscles, you know all those things, I would just think and then write down and then draw at the same time that's how I made it to be easy then understand the neuromuscular junction." (Participant 8)*.

Others prioritised understanding the structural integration of components to create a flow diagram that illustrated how everything worked together *"Its ok, when I study first look into the structure of how the components of the structure are integrated together so that I can have like a flow diagram of how everything works together and with that I couldn't do that" (Participant 1)*. These findings indicate the importance of personalised approaches to learning neurophysiology and highlight the significance of incorporating visualisation techniques and repetition in the teaching of challenging concepts in neurophysiology. This emphasises the need for a variety of teaching strategies that cater to different learning styles, enabling students to overcome learning barriers and deepen their comprehension of the subject matter.

3.6.4 Cramming and rote learning

The study's findings suggest that some participants relied on cramming as a way of preparing for assessments: *"My study method, if I don't understand something from the notes, I refer to YouTube that has videos studying the systems so they explain better like using images and videos so yah and animations. But for some of the things that I did not have time I crammed and passed the exam but could not remember afterwards." (Participant 10).* This finding highlights the limitations of the "cram and forget" method of learning, which is characterised by a short-term retention of knowledge. This suggest that promoting deeper learning strategies that emphasise understanding, retention and application of concepts, is vital in facilitating long-term retention and the development of a robust understanding of the subject matter.

CHAPTER 4: DISCUSSION AND CONCLUSIONS

4.0 Discussion

The current study was designed to explore and describe the undergraduate biomedical students' perceptions of factors that enhance or constrain the learning of neurophysiology at a metropolitan university in South Africa. A qualitative descriptive study in which a general thematic analysis approach was used. Semi-structured interviews were conducted with a purposive sample of 10 male and female undergraduate biomedical students studying Physiology and registered in the Faculty of Health Sciences at a metropolitan university in South Africa. Interview transcripts were coded using MAXQDA for data management and analysed using a general thematic analysis approach as described by (Braun and Clarke, 2006). The results show that students identified prior knowledge of biological concepts from high school, the availability of learning resources, and practical sessions as enhancing the learning of neurophysiology while the amount of work to be covered, language and terminology, the pre-requisite of knowledge of physical sciences such as chemistry and physics, the presence of troublesome knowledge, and potential threshold concepts were identified as factors restricting epistemic access of neurophysiology knowledge. Several topics or concepts in neurophysiology such as the somatic nerve (somatosensory and somatomotor) pathways, functions of the different regions of the brain and special senses were identified as troublesome knowledge since they posed a challenge and acted as a barrier to the learning of neurophysiology. The mechanisms involved in the generation and propagation of action potentials due to their troublesome, transformative, boundedness and irreversible nature was described as potential threshold concepts.

4.1 Factors enabling the learning of neurophysiology

According to findings from our research, students identified that the prior learning of biological concepts, availability of learning resources as well practical sessions allowed them to grasp neurophysiology knowledge.

4.1.1 Prior learning of biological concepts in high school

Participants highlighted that prior knowledge on biological principles from their high school Life Sciences subject assisted them in the learning of neurophysiology. Prior learning of biological concepts in the Life Sciences subject during high school can be very helpful in the learning of neurophysiology as it gives foundational knowledge and comprehension of fundamental biological principles. Students who comprehend ideas like cell biology, genetics, and anatomy in high school will be better able to comprehend and put the information they learn in a neurophysiology course into context. Moreover, understanding the broader concepts of homeostasis and regulation that are taught at high school level can also aid in understanding how the nervous system functions to maintain these processes in the body.

This finding that participants in this study relied on their prior understanding from high school Life Sciences is consistent with the literature on the importance of prior knowledge in learning. Prior knowledge is considered an essential factor in learning and has been shown to influence learning outcomes significantly. Previous studies have shown that learners use their prior knowledge to construct new knowledge and integrate new information into existing cognitive structures (Ausubel, 1968; Novak & Gowin, 1984). Additionally, prior knowledge has been shown to facilitate the retention and recall of new information and to help learners make connections between new and existing knowledge (Bransford, Brown, & Cocking, 2000).

Our findings on the significance of high school prior learning of biological principles in in enhancing the understanding of neurophysiology corroborates with the constructivism learning framework which explains how people acquire knowledge and learn. According to the constructivism learning theory, people build knowledge and meaning from their experiences, hence most students pick up new material by combining it with what they already know (Bada and Olusegun, 2015). The findings are also consistent with the cognitive load theory, which suggests that learning is influenced by the cognitive load imposed on working memory. According to the theory, learning is more effective when learners are provided with a schema or mental model to help them process new information. In this case, the prior knowledge acquired by the participants in high school Life Sciences acted as a schema or mental model to help them process and understand new neurophysiology knowledge.

Effective teaching of physiology, including neurophysiology is underpinned by identifying the students' prior knowledge (Slominski et al., 2017). Students are not blank slates, but rather possess unique prior knowledge, understanding and personal experiences, which have bearing on their learning of neurophysiology concepts. According to Ausubel's meaningful Learning framework, meaningful learning occurs when students can connect new information to their existing knowledge (Ausubel, 1961). We have shown that participants in this study relied a lot on their previous understanding from their high school Life Sciences build-up on and enhance their understanding of new neurophysiology knowledge. More often than not, if new information cannot be linked to existing knowledge meaningful learning may not occur (Learn, 2000). In such circumstances students will resort to rote learning methods as a result of their inability to align new knowledge to existing knowledge. These findings highlight the importance of acknowledging the influence of prior learning experiences when designing and implementing educational programs in the field of neurophysiology.

4.1.2 Availability of learning resources

Our findings show that students identified the availability of online learning material that was provided via the learning management system as factor that enhanced epistemic access neurophysiology. The online resources that were provided to the students during the teaching of neurophysiology included some journal articles, videos and animations, interactive simulations, and case studies in order for the students to understand and apply key concepts in neurophysiology. The availability of online resources and learning material facilitates the learning of neurophysiology by providing access to a wide range of information and resources that can supplement traditional classroom learning (Reinke, 2019).

The finding that students in this study identified the availability of online learning material as a factor that enhanced their epistemic access to neurophysiology is consistent with the findings of previous research. Many studies have demonstrated that online resources can be effective tools for enhancing student learning in a variety of fields, including science and medicine. For example, a study by Cakir and Cakir (2016) found that medical students who used online learning resources had better academic performance than those who did not. Similarly, a study by de Oliveira et al. (2017) found that online resources helped nursing students to learn anatomy and physiology more effectively.

Our findings also corroborate with other studies that have shown that the use of a variety of online resources provides students with access to current research and developments in the field, which can help students stay up-to-date with the latest advances in neurophysiology (Guy et al., 2018). I believe that the online resources that I uploaded on the learning management system (Blackboard) were useful for self-directed learning and for helping students to review and reinforce key concepts outside of class. This can be particularly useful for Physiology students who may benefit from additional practice and review, as the subject matter can be complex and nuanced (Saadeh et al., 2021).

In the context of teaching physiology, the availability of resources can greatly impact students' learning experiences and outcomes. If there is limited access to resources such as equipment, technology, or literature, it could also limit the students' epistemic access to the subject. However availability of resources such as textbooks, videos, simulations, and hands-on activities can all provide students with different experiences and perspectives that they can use to construct their own understanding of the subject matter. For example, the use of computer simulations can help students visualize and explore complex physiological processes that are difficult to observe in real life. Similarly, hands-on activities such as dissections can provide students with a direct and tangible experience of the structures and functions of different physiological systems.

A learning theory that is often associated with the availability of resources in the teaching of physiology is the constructivist theory. Constructivism is a learning theory that emphasizes the active role of the learner in the process of knowledge acquisition (Mintzes, 2020). This theory posits that learners actively construct their own understanding and knowledge through experiences and interactions with their environment, including the resources that are available to them (Grønlien et al., 2021). In the context of this finding, the availability of online learning material provided students with opportunities to construct their own understanding of neurophysiology by engaging with interactive simulations, case studies, and other resources. By interacting with these resources, students were able to build upon their prior knowledge and experiences, which enhanced their understanding of neurophysiology.

The constructivist theory also emphasizes the importance of providing students with a variety of resources and experiences that they can use to construct their own understanding of the subject matter (Grønlien et al., 2021). By doing so, physiology educators can help to ensure that students are able to develop a rich and diverse understanding of neurophysiology, and are better prepared to apply their knowledge in real-world situations.

Another important aspect of online resources is the ability to access them any time and from any location, this can be especially useful for students who have mobility issues (which most students face anyway) or who may not have access to traditional classroom resources. Furthermore, the availability of online resources greatly enhanced the learning experience for the students by providing them with a wealth of information and resources that supplemented and complemented their classroom learning.

4.1.3 Laboratory Practical sessions as enablers of neurophysiology learning

Neurophysiology is a laboratory-based discipline that relies heavily on experimental techniques and data analysis. Without hands-on experience in the laboratory, it can be difficult for students to fully grasp and apply the concepts that they are learning. We have shown that undergraduate biomedical students identified practical sessions as a factor that enable them to understand neurophysiology. Practical laboratory sessions are an important aspect of learning neurophysiology as they provide students with the opportunity to apply and reinforce the theoretical concepts they have learned in during lectures.

Practical sessions can include hands-on experiments, demonstrations, and laboratory work that allow students to directly observe and analyse the workings of the nervous system (Cerchiara et al., 2019). For instance, students can perform experiments to measure neural action potentials, to demonstrate the concept of synaptic transmission, or to observe neural reflexes. Additionally, students can use laboratory equipment and other measuring devices to record and analyse neural signals. I believe that the practical sessions that we did with the students provided them with the opportunity to develop important laboratory skills such as experimental design, data analysis, and the use of scientific equipment. This could be the reasons why the students felt that the practical sessions enhanced their understanding of neurophysiology. It has been shown that such skills are essential for careers in neuroscience, medicine, and other related fields (Robinson et al., 2016). Moreover, practical sessions can also help students to better understand the relevance and applicability of neurophysiology to real-world scenarios. This can foster curiosity and interest in the subject matter and can help to motivate students to continue learning and exploring the neuroscience field.

The learning theory that is often associated with practical sessions in the teaching of physiology is the experiential learning theory, also known as the Kolb's Cycle of Experiential Learning. This theory was proposed by psychologist David Kolb, who argued that learning is a process that occurs through a cycle of four stages: concrete experiences, observation and reflection, formation of abstract concepts, and testing in new situations (Barros et al., 2013).In the context of teaching physiology, I believe that laboratory practical sessions also provide students with concrete experiences that they can observe and reflect upon. For example, through hands-on activities such as recording of action potentials, students can directly observe the functions and structures of the physiological systems they are learning about. This allows them to form a deeper understanding of the abstract neurophysiology concepts and applying what they have learned in new situations, such as problem-solving.

4.2 Factors constraining the learning of neurophysiology

Few studies have been conducted on the factors constraining the students' understanding of neurophysiology (Ranaweera and Montplaisir, 2010). These few studies focused on how students learnt concepts such as central nervous system and peripheral nervous system and their findings showed that students struggled with concepts such as the anatomy of a neuron which resulted in poor knowledge building and the understanding of complex concepts such as reflex arc (Ranaweera and Montplaisir, 2010). While some students in the current study reported that they found it easy to learn and understand neurophysiology, the majority of the interviewed students struggled to understand it.

Most responses from the student participants identified neurophysiology as a complex area with multiple levels of organisation and intricate networks of cells when compared to the other physiological systems. The complexity of the structure of knowledge in neurophysiology may have been difficult for some students to understand and retain the information (Michael, 2007). According to Bernstein's theory of knowledge structure, it is crucial to understand the structure of knowledge in a field and how it can be organised and classified to facilitate learning and understanding (Maton, 2014, Moore, 2006). Due to the abstract nature of some concepts and the intricate details involved, it can be challenging for the students to see the connections and relationships between the different neurophysiology topics and to grasp the overall functioning of the nervous system (Michael, 2007, Michael and McFarland, 2020). Our findings also showed that students grappled with the integrative nature of neurophysiology. The nervous system is closely integrated with other physiological system due to its regulatory role (Rothwell, 2009). This possibly made it difficult for students to isolate the function of the nervous system and how it interacts with other systems.

Challenges associated with the learning physiology have also been reported in the learning of other physiological systems such as the respiratory system (Michael et al., 1999), digestive system (ÖREN, 2011) and the cardiovascular system (Pelaez et al., 2005). However there is little research on the students' perceptions on the factors that limit epistemic access of neurophysiology learning. Research on neurophysiology at undergraduate level is largely absent but has mostly been conducted at postgraduate level (Slominski et al., 2017).

In addition to the complex nature of the neurophysiology knowledge, our findings showed that students identified the quantity of work, language and terminology, pre-requisite knowledge of physical sciences (Chemistry and Physics) as well as troublesome knowledge as the main constraining factors that hold them back from the learning of neurophysiology.

4.2.1 Amount of work covered as a constraining factor

Findings from this study showed that the amount of work that was covered in the neurophysiology section was identified as a constraining factor in the epistemic access of physiology knowledge. For instance, students identified the amount of work that had to be covered for the special senses section as a constraining factor. Data from the students' responses suggests that there is a strong possibility that due to the limited time that they had to cover the content on special senses and the pressure associated with, may have led them to identify special senses are troublesome knowledge. Since all the special senses are covered over a very short period (usually within two weeks), this may have presented the students with cognitive overload and failure of the students to cope with the amount of work.

Cognitive overload occurs when the amount of information presented to a student exceeds their ability to process it effectively as may have been the case with the special senses (Gevins and Smith, 2003). Cognitive overload has a significant impact on the learning of neurophysiology, as it can make it difficult for students to process and retain new information. In the context of learning neurophysiology, cognitive overload can be caused by a number of factors, such as: complex and abstract concepts that are difficult to grasp, a high volume of new information presented in a short period of time, a lack of connections made between new information and previously learned material. When students experience cognitive overload, they may have difficulty retaining new information, and may struggle to understand and apply the material. This can lead to faulty knowledge building resulting in poor performance in assessment tasks, and can impede their ability to progress in the course.

To mitigate the effects of cognitive overload, lecturers can reduce the volume of work by focusing on what is key to the understanding neurophysiology and provide students with a variety of ways to access the material e.g. through text, images, videos, to name but a few. It is also important for lecturers to present information in a clear and organized manner with clear explanations of concepts and examples. I propose that lecturers use techniques such as active learning, spaced repetition and provide opportunities for students to review and reinforce previously learned material, and to practice applying new information in a variety of contexts. Breaking down complex concepts and large chunks of information into smaller and manageable pieces and providing time for students to process the information before moving on to new material has been shown to reduce cognitive overload (Byyny, 2016).

4.2.2 Neurophysiology language and terminology as a constraining factor

The topic of terminology and language used in the learning of neurophysiology emerged as an area that was troublesome, causing difficulty in understanding neurophysiology. Some of the students admitted that the use of many difficult terms acted as a barrier to their understanding hindered them from fully grasping neurophysiology as it took them some time to understand the different terms before they could focus on trying to understand specific concepts in neurophysiology.

In the context of teaching physiology, terminology and language play a crucial role in conveying information and concepts effectively. Students must be able to understand and use the specialized language and terms of the field in order to effectively understand and communicate physiological concepts. However, this can also present a challenge, as the terminology used in physiology can be complex and difficult to understand. A previous study showed that terminology used in the learning of concepts in certain disciplines can be conceptually difficult for students thus imposing barriers to the learning of concepts (Moeller and Fawns, 2018). According to Meyer and Land (2006) the troublesome nature of terminology used in certain disciplines often leads to students oscillating between periods of understanding and frustration with difficult concepts. Part of the disciplinary way of thinking include the acquisition of the language and understanding of the terminology associated with disciplinary concepts (Hill, 2011).

Neurophysiology is a highly specialized field that involves a deep understanding of the structure and function of the nervous system, including the molecular, cellular, and systems-level processes that underlie neural function. This complexity can make it difficult for students to grasp key concepts and make connections between different areas of the subject. Disciplinary language in neurophysiology integrates with all concepts in the neuroscience discipline and the students' daily vocabulary as they undergo training resulting in ontological transformation (Hill, 2020). Student participants in our study identified neurophysiology terminology as a factor that constrained or negatively affected their learning and understanding of certain topics in neurophysiology. This finding corroborates findings from a study (Hill, 2020) who also reported that disciplinary language and terminology are can determine the troublesomeness of concepts. In their study they described TCs in the learning of prosthetics and disciplinary language was identified as troublesome that most participants struggled with initially (Hill, 2011).

Our data also suggests that students had prior exposure to the terminology during their high school Life Science subject. However the use of disciplinary terminology at that level was not contextualized, it was only when they started studying neurophysiology in their first year for their Physiology module that there was some form of conceptual transformation in understanding the purpose for the terminology and its integration with other subjects occurred.

Based on my informal interaction with students, it emerged that students have previously complained that there are many new terms that are difficult to understand or comprehend; as such they spend too much time figuring out the meaning of these resulting in less time being devoted towards conceptual understanding. Horrigan (2018) in his study on the tackling of the threshold concepts in physiology using laboratory classes also identified "*scientific terminology*" that is

used in laboratory classes for scientific communication as difficult for some students. Studies have reported that students faced difficulties grasping terminology or the language necessary to adequately describe or demonstrate their understanding of concepts (Shanahan et al., 2006).
One possible way of assisting the students struggling with terminology is to provide them with a glossary of terms for reference or recommended readings and resources that will assist students before the commencement of and during neurophysiology lectures.

4.2.3 Lack of pre-requisite knowledge in physical sciences as a constraining factor

Our findings showed that students who had inadequate background pre-requisite knowledge from physical sciences (chemistry and physics) struggled to understand certain concepts in neurophysiology. Interviewed participants confirmed that a lack of understanding of chemistry and physics constrained their ability to build neurophysiology knowledge. In most cases undergraduate students fail to understand physiology at the level that they are expected or seem to require more assistance than expected to master concepts that are seemingly easy (Michael, 2007).

The concepts and principles used in neurophysiology are derived from a wide-range of other fields, including biology, physics, and chemistry. In order to understand neurophysiology, students should possess prior knowledge in basic physical sciences such as physics and chemistry. Students may find it challenging to comprehend the links and significance between other sections of neurophysiology if they do not have a strong understanding of how neurophysiology relates to these other fields. Chemistry and Physics are both important in the learning of neurophysiology as they provide the foundational knowledge and understanding of the underlying principles that govern the functioning of the nervous system (Michael and

McFarland, 2020). According to Michael and McFarland (2020) students who are less comfortable with pre-requisite knowledge in chemistry and physics have an impaired ability to understand Physiology. Chemistry, in particular, is important in understanding the chemical processes that occur within the nervous system, such as neurotransmission and synaptic signalling. Most concepts in neurophysiology such the ionic movements across plasma membranes, voltage differences across membranes in the establishment of resting membrane potentials are based on chemical and physical principles (Michael and McFarland, 2020). Understanding the chemical makeup of neurotransmitters and how they interact with receptors is essential for understanding how the nervous system functions. Additionally, an understanding of basic biochemistry is necessary for understanding the metabolism of neurons and how energy is used to maintain neural activity.

Physics on the other hand is important in understanding the electrical processes that occur within the nervous system, such as action potentials and the generation of nerve impulses. This includes understanding concepts such as electrical potentials, current, and resistance, which are fundamental to understanding how the nervous system functions. Moreover, Physics is also important in understanding the mechanics of the nervous system, such as the biomechanics of nerve fibres and the mechanical properties of nerve cells.

We have shown that students that had a limited understanding of pre-requite knowledge of physical sciences knowledge, experienced challenges in understanding certain neurophysiology concepts. Our finding corroborate a study by Michael (2007) who interviewed physiology lecturers on what they perceived as sources of difficulty in learning physiology. They demonstrated that the primary causes of Physiology being challenging for students to learn are the nature of the discipline and what students bring as prior knowledge. It has been acknowledged that students find it difficult to transfer their knowledge from one context to another, especially in the beginning of Physiology lectures. As a result, they frequently find it difficult to use their understanding of physical sciences to understand neurophysiology (Michael, 2007).

It is therefore possible that the students who participated in the current study experienced fragile knowledge building of neurophysiology knowledge and participate fully in the learning process due to their lack of adequate understanding of chemistry and physics (subjects that some students may have found difficult) which underlie physiological processes (Horrigan, 2018).

4.3 Troublesome knowledge and the TC's learning of neurophysiology

Our findings showed that students identified several topics or concepts in neurophysiology such as the somatic nerve (somatosensory and somatomotor) pathways, functions of the different regions of the brain and special senses as such constraining their learning of new physiology knowledge. Although the topics constrained and posed a challenge to their learning of neurophysiology, they were troublesome knowledge and not necessarily threshold concepts. Troublesome knowledge refers to concepts or facts that are difficult for students to understand or remember (Hill, 2020). Troublesome knowledge can be difficult for students to grasp because it is abstract, counterintuitive, or goes against their preconceptions (Meyer and Land, 2006). Threshold concepts, on the other hand, are key ideas or principles in a discipline that are essential for a student to understand in order to progress in that field. Threshold concepts are considered "threshold" because once a student understands them, they can begin to see the subject in a new way and make connections to other areas of study (Nicola-Richmond et al., 2018). In as much as both troublesome knowledge and threshold concepts can be difficult for students to grasp, the key difference is that troublesome knowledge is difficult because it challenges a student's existing understanding, while threshold concepts are difficult because they are essential for understanding the subject and making connections to other areas of study. Troublesome knowledge can be part of threshold concepts, but threshold concepts are not necessarily troublesome knowledge (Hill, 2020, Adler-Kassner et al., 2012).

Findings from this study also showed that students identified the knowledge on the somatic nerve (somatosensory and somatomotor) pathways as a troublesome knowledge. The human body interacts with the environment using receptors whose function is to monitor the changes (stimulus) in the environment. Upon detecting the stimulus, receptors generate action potentials (receptor potential) which are transmitted to the central nervous system (brain and spinal cord) via afferents pathways for further processing and integration. The sensory information (in the form of action potentials) is carried to the brain through specific somatosensory pathways. Once the sensory information has been processed in the central nervous system, motor commands are generated from the motor cortex (a region of the brain) and send to effectors where an appropriate response to the elicited. This knowledge about neural pathways is troublesome and a potential barrier to epistemic access to new knowledge in neurophysiology, in particular the regulatory nature of the central nervous system over the other physiological systems as well as the neuropathology associated with the neural pathways. Our findings corroborate some studies in medical education which reported that, troublesome knowledge in neurosciences could include, but not limited to, complex mechanisms of neural signalling, the functions of different types of neurons, or the relationship between brain structure and function (Moeller and Fawns, 2018).

In order to address troublesome knowledge, I propose that educators make use a variety of techniques such as breaking down the material into smaller, more manageable chunks, providing hands-on activities or demonstrations, and incorporating real-world examples to help students connect the material to their own experiences. Additionally, instructors can use visual aids like diagrams and videos, to help students understand and retain difficult information, use frequent formative assessments, like quizzes, can help identify areas where students are struggling, so that the lecturer can provide additional support. These methods provide students with hands-on experience and encourage active participation in the learning process.

4.3.1 Existence of potential threshold concepts as a constraining factor

The fact that some student participants cognitively struggled with neurophysiological concepts which they later managed to understand seem to be an indication that there could be some threshold concepts in the learning of neurophysiology. It is possible that knowledge may not just be troublesome, it may be that there are couple of threshold concepts that students encountered and are also constraining from ever getting a complete handle on neurophysiology knowledge. Our data showed that threshold was not traversed with certain neurophysiology concepts such as the mechanism involved in the generation and propagation of action potentials. Some of the students just crammed these topics and admitted that they did not know what was going on but just said the words and had no clear understanding of the concepts. Some students pointed out that they initially struggled with understanding how action potentials were created and propagated before they eventually came to understand them with time.

Threshold concepts are key ideas or principles in a discipline that are essential for a student to understand in order to progress in that field (Ross et al., 2010). These concepts are considered "threshold" because once a student understands them, they can begin to see the subject in a new way and make connections to other areas of study such as neuroscience and neurology. Using threshold concepts in teaching can help students to develop a deeper understanding of the subject matter and to apply their knowledge in real-world settings (Land et al., 2016).

The fact that some students identified the generation and propagation of action potentials as troublesome and admitted that they initially struggled to understand before eventually overcoming them, provide evidence that these concepts were TCs that limited their epistemic access. Our findings demonstrate that mechanisms involved in the generation and propagation of action potentials were troublesome. This is due to some students that initially struggled and transformative because after understanding these concepts opened up doors of knowledge for the students. This in turn allowed them to understand more neurophysiology related areas such as muscle physiology, excitable tissues to name but a few.

It is important to note that when students fail to grasp this important troublesome concepts, it will be difficult to acquire any further knowledge on the communication between neurons, a basis of the functioning of the nervous system. It is possible that the mechanisms of action potential generation and transmission imposed a barrier in the learning of additional neurophysiology concepts by the undergraduate students. Meyer and Land (2003) described TCs as 'portals' that open up new and previously inaccessible ways of thinking about something and a transformed way of understanding or interpreting something without which the learner cannot progress. However once the students have grasped these important concepts, it is unlikely that they will forget them.

As a result, the transformative and irreversible nature of the knowledge on the mechanisms involved in the generation and propagation of action potential plays a crucial role in helping students understand other related topics in neurophysiology. There are no specific studies that focused on students' perceptions on the threshold concepts in neurophysiology however, a study by Horrigan (2018) identified some of the threshold concepts in physiology and explored the role of laboratory practical program in helping students to tackle these concepts. It is interesting to note that the identification of nerve physiology as a TC that was reported by the interviewed students in the current study corroborates findings by Horrigan (2018) who also reported that students in their study faced difficulties understanding bioelectricity and action potentials (Horrigan, 2018). Furthermore, a study by Silverthorn (2002) also showed that undergraduate medical students struggle when they learn membrane potentials and events at a synapse suggesting that the mechanism associated with the establishment of resting membrane potentials are troublesome knowledge.

I believe that when it comes to threshold concepts, struggling students can be supported by informing them about the existence of the threshold concepts that were identified in this study, at the beginning of teaching neurophysiology section and this should then be followed by reassuring the students that those who struggle at first will eventually understand them. Students should be reminded that grasping threshold concepts is non-linear, but rather relies on repetition, which in turn should assist them in understanding the troublesome knowledge in neurophysiology. Understanding why students identified some of these concepts as TCs will assist the Physiology educators with an opportunity to design our curriculum, especially the assessment and teaching methods in an effort to meet and address the pedagogical challenges associated with those particular TCs. It has become clear that some of the neurophysiology topics are troublesome to most undergraduate students and these stuck places, or “bottlenecks” to learning, may mark the important “ways of knowing” in neurophysiology.

4.4 Students’ approaches to overcome constraining factors

In the current study, the theme on the strategies that students used to deal with factors constraining the learning of neurophysiology emerged. We have shown that students used a variety of strategies such as the use of recommended and provided resources, YouTube videos, repetition of work and use of diagrams and cramming of difficult concepts to overcome constraining factors of neurophysiology learning. The finding that participants used a variety of resources to understand threshold concepts in neurophysiology is consistent with previous research. Previous studies have also highlighted the importance of using a range of resources in understanding complex concepts in science. According to Alshannag (2016), the use of various resources is important in comprehending difficult concepts because they offer different perspectives and explanations, which cater to the diverse learning needs of students.

Furthermore, van der Hoeven Kraft et al. (2015) argued that the use of multiple resources can foster self-regulated learning as it enables students to take control of their learning by selecting and using resources that they find most helpful. The use of multiple resources to enhance learning aligns with the cognitive theory of multimedia learning (Mayer, 2009). This theory posits that people learn better when information is presented using multiple modes, such as text, images, and audio, as each mode activates different cognitive processes in the brain. Therefore, by providing various resources, lecturers can tap into the different modes of information processing and improve students' learning outcomes.

The finding that YouTube videos were an essential resource for participants to comprehend difficult concepts in neurophysiology is corroborates previous research on the use of online resources in learning. Several studies have reported that online videos, particularly those available on YouTube, are a popular and effective resource for students to learn complex concepts in various fields, including biology and neuroscience. For example, a study by van Gog and colleagues (2015) found that medical students who used YouTube videos to learn about medical procedures had higher scores on a post-test than those who used only text-based materials. Similarly, a study by Mayer and Moreno (2010) found that students who watched a narrated animation on the workings of the human heart had better comprehension and retention of the material than those who read a text-based explanation.

The finding also supports the notion that multimedia resources, such as videos and animations, can enhance learning by providing visual and auditory cues that can help students comprehend and retain information. This is consistent with the cognitive theory of multimedia learning, which suggests that people learn more effectively when information is presented in multiple modalities (such as text, images, and sound) rather than in a single modality.

Our finding on how students used repeatedly go over their work as a strategy to overcome factors limiting epistemic access to the learning of neurophysiology suggests that repetition was used as a coping mechanism to reinforce understanding of complex concepts. Repetition is a well-known and widely used strategy for learning and memory retention. This finding is consistent with previous research that has found repetition to be an effective strategy for learning and memory retention. Research has shown that repetition can help solidify new information in long-term memory, especially when the information is complex or difficult to understand. A study by

Freeman et al (2014) found that active learning strategies, such as repetition and practice, were more effective for improving student performance in STEM courses than traditional lecture-based teaching methods. The authors suggest that repeated exposure to information, combined with active engagement and feedback, can help students retain information and improve their understanding of complex concepts (Freeman et al. 2014).

The finding that some participants relied on cramming as a way of preparing for assessments is consistent with previous research that has found cramming to be a common study strategy among students. Cramming refers to the practice of studying intensively for a short period of time, often just before an exam or assessment. Andrews et al (2011) conducted a study in which they surveyed over 1200 undergraduate biology students to explore their study habits and their perceptions of active learning strategies. The authors found that over half of the students reported using cramming as a study strategy, especially for exams (Andrews et al 2011). The authors suggest that this reliance on cramming may be due to a lack of understanding of effective study strategies and a focus on short-term performance rather than long-term retention and understanding of material.

While cramming may help students remember information in the short-term, it is generally considered to be a less effective study strategy than regular, distributed practice over a longer period of time. Instead, students may benefit from regularly reviewing material over a longer period of time to reinforce their understanding and retention of information. Our findings highlights the need for lecturers to help students develop effective study strategies, such as distributed practice and active learning, to improve their learning and retention of material in biological sciences. Research has shown that distributed practice, or spacing out study sessions over a longer period of time, is more effective for long-term retention and understanding of concepts than cramming.

4.5 Conclusion

The findings from this study extend our understanding of prior research on undergraduate students' perceptions on factors that enable and constrain the learning of neurophysiology. We have shown that factors such as the prior learning of biological concepts, availability of learning resources and practical sessions enable, while the quantity of work, language and terminology, pre-requisite knowledge of physical sciences (chemistry and physics) and troublesome knowledge, constrained the learning of neurophysiology concepts. It also emerged that topics such as special senses, somatosensory pathways, structure and functions of brain regions were perceived as troublesome while the generation of action potentials were identified as a threshold concept due its troublesomeness and transformative nature. Moreover, our study is the first to systematically document students' perceptions on enabling and factors constraining epistemic access in the learning of neurophysiology. Our research extend the work that was conducted by Hay et al. (2013) and Slominski et al. (2017) on providing pedagogical approaches to the teaching and learning of basic undergraduate neurophysiology.

According to my knowledge, this is the first study in which students identified several concepts namely such as the generation and propagation of action potentials, the somatosensory and somatomotor pathways, terminology, functions of the brain regions and special senses as threshold concepts in the learning of neurophysiology. These concepts may be related to each other since the transmission of sensory information and motor commands in somatosensory and somatomotor pathways respectively rely on the generation and propagation of action potentials along neurons and nerve tracts. These findings provide clarity on the potential barriers to learning neurophysiology, thus opening up an opportunity for the lecturers to support the students through curriculum design, teaching methods and assessments. The variations in identification of troublesome knowledge by students and their perceptions of troublesome knowledge may assist lecturers develop pedagogical strategies in the teaching of neurophysiology topics so that students can overcome barriers to learning and transition from their previous views of threshold concepts in neurophysiology thus enabling their understanding of neurophysiology to be transformed by using different ways of teaching. Acknowledging the existence of variations in the students' perceptions of the factors enabling and constraining the learning of neurophysiology can facilitate the provision of support by lecturers to students in overcoming their barriers to learning neurophysiology as well as integrating and connecting the involvement of the nervous system in regulating other systems for the maintenance of homeostasis. Moreover, the factors enabling and constraining that were identified in the current study by the students may help determine whether students have actually grasped the threshold concepts thus providing the lecturer with an opportunity to assess them at the highest level of knowledge and competence in neurophysiology.

In conclusion, this research report aimed to explore and describe undergraduate biomedical students' perceptions of factors that enhance or constrain the learning of neurophysiology at a metropolitan university in South Africa. The study found that students' prior learning of biological concepts in high school, availability of learning resources, and practical sessions were perceived as enhancing the learning of neurophysiology. On the other hand, factors such as the amount of work to be covered, language and terminology, pre-requisite knowledge of physical sciences, and the existence of troublesome knowledge and potential threshold concepts were perceived as constraining factors in the learning of neurophysiology. Troublesome knowledge was identified in the areas of somatosensory and somatomotor pathways, functions of different regions of the brain, and special senses, while the generation and propagation of action potentials were perceived as a threshold concept. These findings highlight the importance of identifying factors that affect students' epistemic access to neurophysiology and provide insights for educators to develop effective teaching strategies to enhance students' learning of neurophysiology. Future studies can build on these findings to develop interventions that address the identified constraining factors and facilitate the learning of neurophysiology for all students.

4.6 Recommendations and future prospects

Ideally, the main aim is always to ensure that the students understand difficult concepts to a large extent and in so doing refrain from rote learning or superficial understanding of concepts. There is a need to explore ways (through curriculum design, teaching methods and assessment criteria), to assist students to bridge the gaps between mastery of neurophysiology. By probing and exploring the students’ perceptions of factors that constrain or enhance the learning of in neurophysiology, I was able to identify areas where specific support can be provided to students. Although it is possible that different classes in different years of study may have different perceptions on what these factors are, this study provides a foundation on which future studies on factors that constrain or enhance the learning of neurophysiology can be based. Following the identification of factors that constrain or enhance the learning of neurophysiology and description of troublesome knowledge and potential threshold concepts, I recommend the inclusion of support material and resources into the curriculum in order to support the students who may be struggling to understand neurophysiology. Teaching strategies that focus on the identified troublesome topics or concepts may be utilised in the teaching practice, however caution must be exercised when adopting teaching strategies that focus on the explicit teaching of TCs to avoid teaching TCs at the expense of other key concepts (Nicola-Richmond et al., 2018).

Incomplete knowledge building and failure to progress after encountering factors constraining the learning of neurophysiology such as troublesome knowledge and TCs can lead to frustration and sometimes hopelessness among students, especially considering that some of them may have to repeat the module. In an effort to help the students deal with constraining factors such as troublesome knowledge and TCs, it may be useful to inform the students before the commencement of neurophysiology lectures about the existence of such factors and inform them that some will grasp these concepts easily while some may struggle to understand them at first. This should then be followed by reassuring the students that despite the variations in how soon they will grasp the TCs, those who struggle at first will eventually understand the TCs. This approach will ensure that the students are adequately prepared to deal with any future troublesome knowledge and TCs that they may encounter in the learning of neurophysiology. Another approach that I would recommend is the use of mind maps in the teaching of neurophysiology. Such visual representations can aid students in understanding the interrelationships between different concepts and help them grasp the broader picture of neurophysiological principles. Mind maps can also serve as a complementary tool to support students' learning and provide them with a clearer understanding of neurophysiological concepts. Moreover, students may be more comfortable with handling the initial struggle associated with the learning of neurophysiology TCs if they know beforehand about their existence. Students should also be reminded that grasping threshold concepts is non-linear, but rather relies on repetition, which in most cases assist the students in understanding the troublesome knowledge in neurophysiology.

There is also a need to constructively align the teaching methods to the learning outcomes and the assessment criteria. By defining expectations at the beginning of neurophysiology lectures, one will assist the students to recognize what it means to understand neurophysiology and its learning thereof (Essop and Beselaar, 2022). It has been shown in the current study and corroborated by other physiology education researchers (Michael, 2007) that most students believe that understanding physiological phenomena requires memorizing concepts. It would be of paramount importance to set assessments that require more than regurgitation of memorized facts. I recommend and propose that a similar approach be applied to the teaching of other conceptually difficult areas in undergraduate human physiology.

We have shown the significance of prior knowledge in biological and physical sciences, especially chemistry, in the learning of neurophysiology. Some students could not align new knowledge with prior knowledge, resulting in failure to progress and grasp the troublesome knowledge. There is therefore a need to implement pedagogical strategies to find out what students know (or not) before the commencement of lectures. One such approach that has been proposed by Kutchai (2006) is the use of "*carefully crafted pencil-and-paper pre-test*" which involve asking students questions about certain physiology content, in an effort to gauge how much prior knowledge students possess before commencement with lectures.

4.7 Limitations of the study

We recognise that there were some limitations to this study and the findings from this study should be viewed within the context of these limitations as described below.

1) In this study there was a limited number of respondents. It is possible that the participants represent the proportion of students who were enthusiastic, loved and most likely engaged with Physiology. In light of the low number of the students that participated in this study, the current study may not necessarily present all the neurophysiology areas that present difficulty for students. It is therefore plausible there may be more factors that enhance or constrain the learning of neurophysiology that were not identified. Although the turnout was low, such that our findings may not be representative of the entire class, we collected enough data to at least gain some insights into the students' perception on the learning of neurophysiology, information which can be useful in the ongoing development of the curriculum , assessments and teaching methods for future students.

2) In this study only students' perceptions of factors that enhance or constrain the learning of neurophysiology were explored. In order to confirm the validity of these factors that were identified and described by the students, it would have been important to include the physiology lecturers in the study. It would have been ideal to include the lecturers in the study in order to get a holistic understanding of perceptions of factors that enhance or constrain the learning of neurophysiology (from students) and their teaching (from lecturers). The TC framework is considered as complex and troublesome in itself, such that relying on students to identify the TCs and share their perceptions may not have been enough to get a holistic understanding of the TCs in neurophysiology without including the educators' perceptions. Several authors (Moeller and Fawns, 2018) have emphasized on the significance of engaging both students and lecturer when investigating perceptions in medical education. It remains a challenge to determine the degree to which identified factors were enhancing or limiting epistemic access to the learning of neurophysiology

since this depends on the individual experience of the students such that what may be enhancing or constraining for one student may not necessarily be for another. For instance, such disagreements on what may be enhancing or constraining epistemic access has been raised in a previous study by Moeller and Fawns (2018) in which they interviewed experts on the troublesome nature of certain concepts in the interpretation of electroencephalograms. Future studies should be designed in such a way that lecturers' perceptions on threshold concepts will also be investigated.

3) During my research, I encountered practical constraints that influenced the duration of the interviews. While I acknowledge the importance of allowing sufficient time for in-depth interviews, it was challenging to allocate extended periods for interviews due to various factors. I found that many interviews had to be scheduled between classes or towards the end of the day when students had other commitments and the pressure to arrange transportation to go home. It is worth noting that despite my efforts to accommodate additional time, the majority of students were unable to stay longer for the interviews. However, I did have a few exceptional cases where some students were prepared to provide extra time.

REFERENCES

ADLER-KASSNER, L., MAJEWSKI, J. & KOSHNICK, D. The Value of Troublesome Knowledge: Transfer and Threshold Concepts in Writing and History. Composition Forum, 2012. ERIC.

ANDERTON, R. & CHIVERS, P. 2016. Predicting academic success of health science students for first year anatomy and physiology. *International Journal of Higher Education,* 5.

AUSUBEL, D. P. 1961. In defense of verbal learning. *Educational Theory*, 11**,** 15-25.

BADA, S. O. & OLUSEGUN, S. 2015. Constructivism learning theory: A paradigm for teaching and learning. *Journal of Research & Method in Education,* 5**,** 66-70.

BAILLIE, C., BOWDEN, J. A. & MEYER, J. H. 2013. Threshold capabilities: threshold concepts and knowledge capability linked through variation theory. *Higher Education,* 65**,** 227-246.

BARRADELL, S. & PESETA, T. 2018. Integrating threshold concepts and ways of thinking and practising: Supporting physiotherapy students to develop a holistic view of the profession through concept mapping. *International Journal of Practice-based Learning in Health and Social Care,* 6**,** 24-37.

BARROS, C., LEÃO, C. P., SOARES, F., MINAS, G. & MACHADO, J. Students' perspectives on remote physiological signals acquisition experiments. 2013 1st International Conference of the Portuguese Society for Engineering Education (CISPEE), 2013. IEEE, 1-8.

BEATTIE IV, V., COLLINS, B. & MCINNES, B. 1997. Deep and surface learning: a simple or simplistic dichotomy? *Accounting education,* 6**,** 1-12.

BERNSTEIN, B. 1977. Class Codes and Control Volume 3: towards a theory of educa-tional transmissions. London, RKP.

BERNSTEIN, B. 2003. *Class, codes and control: Applied studies towards a sociology of language*, Psychology Press.

BIGGS, J. 1996. Enhancing teaching through constructive alignment. *Higher education,* 32**,** 347-364.

BRAUN, V. & CLARKE, V. 2006. Using thematic analysis in psychology. *Qualitative research in psychology,* 3**,** 77-101.

BYYNY, R. L. 2016. Information and cognitive overload. *Pharos*.

CASOTTI, G., RIESER-DANNER, L. & KNABB, M. T. 2008. Successful implementation of inquiry-based physiology laboratories in undergraduate major and nonmajor courses. *Advances in Physiology Education,* 32**,** 286-296.

CERCHIARA, J. A., KIM, K. J., MEIR, E., WENDEROTH, M. P. & DOHERTY, J. H. 2019. A new assessment to monitor student performance in introductory neurophysiology: Electrochemical Gradients Assessment Device. *Advances in physiology education,* 43**,** 211-220.

CLARKE, V. & BRAUN, V. 2014. Thematic analysis. *Encyclopedia of critical psychology.* Springer.

COLTHORPE, K. & AINSCOUGH, L. 2021. Do-it-yourself physiology labs: Can hands-on laboratory classes be effectively replicated online? *Advances in Physiology Education,* 45**,** 95-102.

CONNELLY, L. M. 2016. Trustworthiness in qualitative research. *Medsurg Nursing,* 25**,** 435.

CROOKES, P. A., LEWIS, P. A., ELSE, F. C. & CROOKES, K. 2020. Current issues with the identification of threshold concepts in nursing. *Nurse Education in Practice,* 42**,** 102682.

DANIELS, H. 2004. Activity theory, discourse and Bernstein. *Educational Review,* 56**,** 121-132.

DAVIES, P. & MANGAN, J. 2007. Threshold concepts and the integration of understanding in economics. *Studies in Higher Education,* 32**,** 711-726.
DHAI, A. & MCQUOID-MASON, D. 2011. Confidentiality. *Bioethics, Human Rights and Health Law: Principles and Practice. Claremont: Juta,* 88.
DHAI, A., MCQUOID-MASON, D. & VAN BOGAERT, D. 2011. Ethical concepts, theories and principles and their application to healthcare. *Bioethics, Human Rights and Health Law: Principles and Practice***,** 3-15.
DOODY, O. & NOONAN, M. 2013. Preparing and conducting interviews to collect data. *Nurse researcher,* 20.
ESSOP, M. F. & BESELAAR, L. 2022. The implementation of active learning practices in a South African physiology class: a follow-up study. *Advances in Physiology Education,* 46**,** 1-10.
ESTERMAN, M., CHIU, Y.-C., TAMBER-ROSENAU, B. J. & YANTIS, S. 2009. Decoding cognitive control in human parietal cortex. *Proceedings of the National Academy of Sciences,* 106**,** 17974-17979.
FORTUNE, T. & KENNEDY-JONES, M. 2014. Occupation and its relationship with health and wellbeing: The threshold concept for occupational therapy. *Australian Occupational Therapy Journal,* 61**,** 293-298.
FYRENIUS, A., SILÉN, C. & WIRELL, S. 2007a. Students' conceptions of underlying principles in medical physiology: an interview study of medical students' understanding in a PBL curriculum. *Advances in Physiology Education,* 31**,** 364-369.
FYRENIUS, A., WIRELL, S. & SILÉN, C. 2007b. Student approaches to achieving understanding—approaches to learning revisited. *Studies in Higher Education,* 32**,** 149-165.
GEVINS, A. & SMITH, M. E. 2003. Neurophysiological measures of cognitive workload during human-computer interaction. *Theoretical issues in ergonomics science,* 4**,** 113-131.
GRIFFIN, J. D. 2003. Technology in the teaching of neuroscience: Enhanced student learning. *Advances in Physiology Education,* 27**,** 146-155.
GRØNLIEN, H. K., CHRISTOFFERSEN, T. E., RINGSTAD, Ø., ANDREASSEN, M. & LUGO, R. G. 2021. A blended learning teaching strategy strengthens the nursing students' performance and self-reported learning outcome achievement in an anatomy, physiology and biochemistry course–A quasi-experimental study. *Nurse Education in Practice,* 52**,** 103046.
GUBA, E. G. & LINCOLN, Y. S. 1994. Competing paradigms in qualitative research. *Handbook of qualitative research,* 2**,** 105.
GUPTA, R. & GROVER, R. 2021. Case-based learning in neurophysiology: An educational paradigm for preparing undergraduate medical students for better clinical acumen. *Indian Journal of Health Sciences and Biomedical Research (KLEU),* 14**,** 84.
GUY, R., BYRNE, B. & DOBOS, M. 2018. Optional anatomy and physiology e-learning resources: student access, learning approaches, and academic outcomes. *Advances in physiology education*.
HANEEF, Z., CHIANG, S., RUTHERFORD, H. C. & ANTONY, A. R. 2017. A survey of neurophysiology fellows in the United States. *Journal of clinical neurophysiology: official publication of the American Electroencephalographic Society,* 34**,** 179.

HAY, D. B., WILLIAMS, D., STAHL, D. & WINGATE, R. J. 2013. Using drawings of the brain cell to exhibit expertise in neuroscience: exploring the boundaries of experimental culture. *Science Education,* 97**,** 468-491.
HILL, S. Knocking on the door: how do students enter the disciplinary community of practice? Fifth Education in a Changing Environment Conference Book 2009: Critical Voices, Critical Times, 2011. Informing Science, 99.
HILL, S. 2020. The difference between troublesome knowledge and threshold concepts. *Studies in Higher Education,* 45**,** 665-676.
HMELO-SILVER, C. E. & BARROWS, H. S. 2008. Facilitating collaborative knowledge building. *Cognition and instruction,* 26**,** 48-94.
HORRIGAN, L. A. 2018. Tackling the threshold concepts in physiology: what is the role of the laboratory class? *Advances in physiology education,* 42**,** 507-515.
JANSEN, J. D. 1998. Curriculum reform in South Africa: A critical analysis of outcomes-based education. *Cambridge journal of education,* 28**,** 321-331.
KRONTIRIS-LITOWITZ, J. 2003. Using manipulatives to improve learning in the undergraduate neurophysiology curriculum. *Advances in physiology education,* 27**,** 109-119.
KUTCHAI, H. Reflections of a medical school teacher. San Francisco, CA: Experimental Biology Symposium, 2006.
LAING, T., SHEEN, J., NICOLA-RICHMOND, K., PÉPIN, G. & O'SHEA, M. 2021. The utility of threshold concepts for clinical psychology education programmes. *Clinical Psychologist,* 25**,** 316-328.
LAND, R., COUSIN, G., MEYER, J. H. & DAVIES, P. 2006a. Implications of threshold concepts for course design and evaluation. *Overcoming barriers to student understanding: Threshold concepts and troublesome knowledge***,** 195-206.
LAND, R., COUSIN, G., MEYER, J. H. & DAVIES, P. 2006b. Implications of threshold concepts for course design and evaluation. *Overcoming barriers to student understanding threshold concepts and troublesome knowledge***,** 195-206.
LAND, R., MEYER, J. H. & FLANAGAN, M. T. 2016. *Threshold concepts in practice,* Springer.
LAND, R., RATTRAY, J. & VIVIAN, P. 2014. Learning in the liminal space: A semiotic approach to threshold concepts. *Higher Education,* 67**,** 199-217.
LEARN, H. P. 2000. Brain, mind, experience, and school. *Committee on Developments in the Science of Learning*.
MACKAY, W. 2000. Responding to cognitive overload: Co-adaptation between users and technology. *Intellectica,* 30**,** 177-193.
MAGUIRE, M. & DELAHUNT, B. 2017. Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *All Ireland Journal of Higher Education,* 9.
MATON, K. 2014. Building powerful knowledge: The significance of semantic waves. *Knowledge and the future of the curriculum: International studies in social realism***,** 181-197.
MAYER, R. E. 2009. Constructivism as a theory of learning versus constructivism as a prescription for instruction. *Constructivist Instruction.* Routledge.
MCFARLAND, J. L. & MICHAEL, J. A. 2020. Reflections on core concepts for undergraduate physiology programs. *Advances in Physiology Education,* 44**,** 626-631.
MEEK, S. & JAMIESON, S. 2014. Threshold concepts and troublesome knowledge in the first year curriculum at a UK medical school [Poster].

MEYER, J. & LAND, R. 2003. *Threshold concepts and troublesome knowledge: Linkages to ways of thinking and practising within the disciplines*, Citeseer.

MEYER, J. H. & LAND, R. 2006. Threshold concepts and troublesome knowledge: An introduction. *Overcoming barriers to student understanding.* Routledge.

MICHAEL, J. 2007. What makes physiology hard for students to learn? Results of a faculty survey. *Advances in physiology education,* 31**,** 34-40.

MICHAEL, J. & MCFARLAND, J. 2020. Another look at the core concepts of physiology: revisions and resources. *Advances in Physiology Education,* 44**,** 752-762.

MICHAEL, J., MODELL, H., MCFARLAND, J. & CLIFF, W. 2009. The "core principles" of physiology: what should students understand? *Advances in Physiology Education,* 33**,** 10-16.

MICHAEL, J. A., RICHARDSON, D., ROVICK, A., MODELL, H., BRUCE, D., HORWITZ, B., HUDSON, M., SILVERTHORN, D., WHITESCARVER, S. & WILLIAMS, S. 1999. Undergraduate students' misconceptions about respiratory physiology. *Advances in Physiology Education,* 277**,** S127.

MIDDENDORF, J. & PACE, D. 2004. Decoding the disciplines: A model for helping students learn disciplinary ways of thinking. *New directions for teaching and learning,* 2004**,** 1-12.

MINTZES, J. J. 2020. From constructivism to active learning in college science. *Active learning in college science: The case for evidence-based practice***,** 3-12.

MOELLER, J. J. & FAWNS, T. 2018. Insights into teaching a complex skill: Threshold concepts and troublesome knowledge in electroencephalography (EEG). *Medical teacher,* 40**,** 387-394.

MOORE, R. 2006. Knowledge structures and intellectual fields: Basil Bernstein and the sociology of knowledge. *Knowledge, power and educational reform.* Routledge.

NEVE, H., WEARN, A. & COLLETT, T. 2016. What are threshold concepts and how can they inform medical education? *Medical teacher,* 38**,** 850-853.

NICOLA-RICHMOND, K., PÉPIN, G., LARKIN, H. & TAYLOR, C. 2018. Threshold concepts in higher education: A synthesis of the literature relating to measurement of threshold crossing. *Higher Education Research & Development,* 37**,** 101-114.

NOWELL, L. S., NORRIS, J. M., WHITE, D. E. & MOULES, N. J. 2017. Thematic analysis: Striving to meet the trustworthiness criteria. *International journal of qualitative methods,* 16**,** 1609406917733847.

ÖREN, F. Ş. 2011. An analysis of pre-service teachers' drawings about the digestive system in terms of their gender, grade levels, and opinions about the method and subject. *International Journal of Biology Education,* 1**,** 1-22.

PAPPAS, C. 2014. Cognitive load theory and instructional design. *Diakses dari http://elearningindustry. com/cognitive-load-theory-andinstructional-design*.

PARK, E.-J. & LIGHT, G. 2010. Identifying a potential threshold concept in nanoscience and technology: Engaging theory in the service of practice. *Threshold concepts and transformational learning.* Brill Sense.

PELAEZ, N. J., BOYD, D. D., ROJAS, J. B. & HOOVER, M. A. 2005. Prevalence of blood circulation misconceptions among prospective elementary teachers. *Advances in Physiology Education,* 29**,** 172-181.

PERKINS, D. 1999. The many faces of constructivism. *Educational leadership,* 57**,** 6-11.

PERKINS, D. 2006. Constructivism and troublesome knowledge. *Overcoming barriers to student understanding: Threshold concepts and troublesome knowledge,* 1**,** 33-47.

RANAWEERA, S. P. N. & MONTPLAISIR, L. M. 2010. Students' illustrations of the human nervous system as a formative assessment tool. *Anatomical Sciences Education,* 3**,** 227-233.
RAYMOND, J., SEALEY, R., NAUMANN, F., ROONEY, K., ENGLISH, T., BARRY, B. & GROELLER, H. 2020. Development of core clinical learning competencies for Australian exercise physiology students. *Journal of Clinical Exercise Physiology,* 9**,** 1-9.
REINKE, N. B. 2019. Promoting student engagement and academic achievement in first-year anatomy and physiology courses. *Advances in physiology education,* 43**,** 443-450.
ROBINSON, V., KING, R., RYAN, C. G. & MARTIN, D. J. 2016. A qualitative exploration of people's experiences of pain neurophysiological education for chronic pain: the importance of relevance for the individual. *Manual Therapy,* 22**,** 56-61.
RODGER, S., TURPIN, M. & O'BRIEN, M. 2015. Experiences of academic staff in using threshold concepts within a reformed curriculum. *Studies in Higher Education,* 40**,** 545-560.
ROSS, P. M., TAYLOR, C. E., HUGHES, C., KOFOD, M., WHITAKER, N., LUTZE-MANN, L. & TZIOUMIS, V. 2010. Threshold concepts: Challenging the way we think, teach and learn in biology. *Threshold concepts and transformational learning.* Brill Sense.
ROTHWELL, J. 2009. Meet the brain: neurophysiology. *International review of neurobiology,* 86**,** 51-65.
RUTKOWSKI, A.-F. & SAUNDERS, C. S. 2018. *Emotional and cognitive overload: the dark side of information technology*, Routledge.
SAADEH, K., HENDERSON, V., PARAMASIVAM, S. J. & JEEVARATNAM, K. 2021. To what extent do preclinical veterinary students in the UK utilize online resources to study physiology. *Advances in Physiology Education*.
SHANAHAN, M. P., FOSTER, G. & MEYER, J. H. 2006. Operationalising a threshold concept in economics: A pilot study using multiple choice questions on opportunity cost. *International Review of Economics Education,* 5**,** 29-57.
SHARPLES, M., DE ROOCK, R., FERGUSON, R., GAVED, M., HERODOTOU, C., KOH, E., KUKULSKA-HULME, A., LOOI, C.-K., MCANDREW, P. & RIENTIES, B. 2016. Innovating pedagogy 2016: Open University innovation report 5.
SHULMAN, L. S. 1986. Those who understand: Knowledge growth in teaching. *Educational researcher,* 15**,** 4-14.
SILVERTHORN, D. U. 2002. Uncovering misconceptions about the resting membrane potential. *Advances in physiology education,* 26**,** 69-71.
SINGH, P. 2002. Pedagogising knowledge: Bernstein's theory of the pedagogic device. *British journal of sociology of education,* 23**,** 571-582.
SLOMINSKI, T. N., MOMSEN, J. L. & MONTPLAISIR, L. M. 2017. Drawing on student knowledge of neuroanatomy and neurophysiology. *Advances in physiology education,* 41**,** 212-221.
STURGES, D. & MAUNER, T. 2013. Allied health students' perceptions of class difficulty: the case of undergraduate human anatomy and physiology classes. *Internet Journal of Allied Health Sciences and Practice,* 11**,** 9.
TREVORS, G. J., MUIS, K. R., PEKRUN, R., SINATRA, G. M. & MUIJSELAAR, M. M. 2017. Exploring the relations between epistemic beliefs, emotions, and learning from texts. *Contemporary Educational Psychology,* 48**,** 116-132.

TUFTS, M. A. & HIGGINS-OPITZ, S. B. 2009. What makes the learning of physiology in a PBL medical curriculum challenging? Student perceptions. *Advances in physiology education,* 33**,** 187-195.

VARPIO, L., AJJAWI, R., MONROUXE, L. V., O'BRIEN, B. C. & REES, C. E. 2017. Shedding the cobra effect: problematising thematic emergence, triangulation, saturation and member checking. *Medical education,* 51**,** 40-50.

VERDUGO, R. J. & MATAMALA, J. M. 2022. Education and training in clinical neurophysiology: Actual state and future needs. *Clinical Neurophysiology Practice,* 7**,** 127.

WEBB, A. 2015. Research interviews in the scholarship of teaching and learning. *Transformative Dialogues: Teaching and Learning Journal,* 8.

WENGER, E. 2010. Communities of practice and social learning systems: the career of a concept. *Social learning systems and communities of practice.* Springer.

YORKE-BARBER, P., ATKINSON, L., POSSIN, G. & WOODALL, L. Light bulb moments: identifying information research threshold concepts for fourth year engineering students. 19th Annual Conference of the Australasian Association for Engineering Education: To Industry and Beyond; Proceedings of the, 2008. Institution of Engineers, Australia, 349.

APPENDICES

Appendix 1: Plagiarism Declaration

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I Associate Professor Trevor Tapiwa Nyakudya (Student number: 0718789E) am a student registered for the degree of Master of Health Science Education in the academic year 2023.

I hereby declare the following:

- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection) software indicating the level of plagiarism in my research document.

Signature: ______________ Date: 30 March 2023

Appendix 2: University of the Witwatersrand Human Research Ethics Committee (Non-Medical) clearance certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

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

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H19/10/30**
PROJECT TITLE	Students' perceptions of learning treshold concepts in Neurophysiology: A qualitative study
INVESTIGATOR(S)	Dr T Nyakudya
SCHOOL/DEPARTMENT	Centre for Health Science Education/
DATE CONSIDERED	18 October 2019
DECISION OF THE COMMITTEE	Approved
EXPIRY DATE	12 December 2022

DATE 13 December 2019 **CHAIRPERSON** (Professor J Knight)

cc: Supervisor : Professor S Moch

DECLARATION OF INVESTIGATOR(S)

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

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

_______________ Signature ____/____/____ Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix 2A: University of the Witwatersrand Registrar's permission letter

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

OFFICE OF THE DEPUTY REGISTRAR

07 January 2020

Trevor Nyakudya
Student number 0718789e
MA Health Science Education
Centre for Health Science Education

TO WHOM IT MAY CONCERN

"Students' perceptions of learning threshold concepts in neurophysiology at a South African university: A qualitative study"

This letter serves to confirm that the above project has received permission to be conducted on University premises, and/or involving staff and/or students of the University as research participants. In undertaking this research, you agree to abide by all University regulations for conducting research on campus and to respect participants' rights to withdraw from participation at any time.

If you are conducting research on certain student cohorts, year groups or courses within specific Schools and within the teaching term, permission must be sought from Heads of School or individual academics.

Ethical clearance has been obtained: (Protocol number: H19/10/30)

Research duration: (1 year)

Nicoleen Potgieter
University Deputy Registrar

Private Bag 3, Wits, 2050, South Africa | **T** +27 11 717 1204/8 | **F** +27 86 553 2271 | www.wits.ac.za

Appendix 3: University of Johannesburg Research Ethics Committee Clearance Certificate

UNIVERSITY OF JOHANNESBURG

FACULTY OF HEALTH SCIENCES
RESEARCH ETHICS COMMITTEE

NHREC Registration: REC 241112-035

ETHICAL CLEARANCE LETTER
(RECX 2.1)

Student/Researcher Name	Nyakudya, T	Student Number	-
Supervisor Name	-	Co-Supervisor Name	-
Department	Human Anatomy and Physiology		
Qualification	Non Degree Purposes		
Research Title	Students' Perception of Learning Threshold Concepts in Neurophysiology: A Qualitative Study		
Date	20 November 2019	Clearance Number	REC-01-75-2019

Approval of the research proposal with details given above is granted, subject to any conditions under 1 below, and is valid until 20 November 2020.

1. **Conditions*:**
None

2. **Renewal:**
It is required that this ethical clearance is renewed annually, within two weeks of the date indicated above. Renewal must be done using the Ethical Clearance Renewal Form (REC 10.0), to be completed and submitted to the Faculty Administration office. *See Section 12 of the REC Standard Operating Procedures.*

3. **Amendments:**
Any envisaged amendments to the research proposal that has been granted ethical clearance must be submitted to the REC using the Research Proposal Amendment Application Form (REC 8.0) prior to the research being amended. Amendments to research may only be carried out once a new ethical clearance letter is issued. *See Section 13 of the REC Standard Operating Procedures.*

4. **Adverse Events, Deviations or Non-compliance:**
Adverse events, research proposal deviations or non-compliance must be reported within the stipulated time-frames using the Adverse Event Reporting Form (REC 9.0). *See Section 14 of the REC Standard Operating Procedures.*

The REC wishes you all the best for your studies.

Yours sincerely,

Prof. Christopher Stein
Chairperson: REC
Tel: 011 559 6564

Appendix 3A: University of Johannesburg institutional permission letter

UNIVERSITY OF JOHANNESBURG

28 October 2019

Dr T Nyakudya
University of Johannesburg
Faculty of Health Sciences

Dear Dr Nyakudya

PERMISSION TO CONDUCT RESEARCH AT THE UNIVERSITY OF JOHANNESBURG

The proposal and research instruments for the research study titled *Students' Perceptions of Learning Threshold Concepts in Neurophysiology: A Qualitative Study* were reviewed. Permission is granted to the conduct this study at UJ.

Sincerely

Dr Carol Nonkwelo
Executive Director: Research and Innovation
Email: cnonkwelo@uj.ac.za

Appendix 3B: Research study information

DEPARTMENT OF HUMAN ANATOMY AND PHYSIOLOGY

RESEARCH STUDY INFORMATION LETTER

REC 11.0

15 November 2019

Good Day

My name is Dr Trevor Nyakudya **I would like to invite you to participate** in a research study on **Students' perceptions of learning threshold concepts in neurophysiology: a qualitative study"**

Before you decide on whether to participate, I would like to explain to you why the research is being done and what it will involve for you. **I will go through the information letter with you and answer any questions you have.** This should take about 45 to 60 minutes. The study is part of a research project being completed as a requirement for a Physiology education general research in Physiology education through the University of Johannesburg.

THE PURPOSE OF THIS STUDY is to the aim of the proposed study is to explore the students' perceptions of threshold concepts in neurophysiology.

Below, I have compiled a set of questions and answers that I believe will assist you in understanding the relevant details of participation in this research study. Please read through these. If you have any further questions I will be happy to answer them for you.

1. **DO I HAVE TO TAKE PART?** No, you don't have to. It is up to you to decide to participate in the study. I will describe the study and go through this information sheet. If you agree to take part, I will then ask you to sign a consent form.
2. **WHAT EXACTLY WILL I BE EXPECTED TO DO IF I AGREE TO PARTICIPATE?** The participant will be expected to participate in an interview session where they will answer some questions probing their perceptions on their learning of neurophysiological threshold concepts.
3. **Section deleted as it is not applicable to the current study.**
4. **APPROXIMATELY HOW LONG WILL MY PARTICIPATION TAKE?** Your participation will take approximately 45-60 minutes.
5. **WHAT WILL HAPPEN IF I WANT TO WITHDRAW FROM THE STUDY?** If you decide to participate, you are free to withdraw your consent at any time without giving a reason and without any consequences. If you wish to withdraw your consent, you should inform me as soon as possible.

6. **Section deleted as it is not applicable to the current study.**

7. **IF I CHOOSE TO PARTICIPATE, WILL THERE BE ANY EXPENSES FOR ME, OR PAYMENT DUE TO ME?** You will not be paid to participate in this study and you will not bear any expenses
8. **IF I CHOOSE TO PARTICIPATE, WHAT ARE THE RISKS INVOLVED?** There are no anticipated risks if you choose to participate in this study
9. **IF I CHOOSE TO PARTICIPATE, WHAT ARE THE BENEFITS INVOLVED?** Understanding of students' perceptions on how they learn threshold concepts in neurophysiology could clarify areas where intervention will improve the learning of neurophysiology by undergraduate students. This information will help to transform the way lecturers design the neurophysiology curriculum and how students are supported in their quest to achieve mastery of neurophysiology and the regulation of the other body systems.
10. **WILL MY PARTICIPATION IN THIS STUDY BE KEPT CONFIDENTIAL?** All reasonable efforts will be made to keep your personal information confidential and respect your right to privacy. This includes replacing your identifying personal information with a number that only I and my research supervisor will know. You will not be identified in any research reports that are published. Under some circumstances, such as when required to do so by a court of law, I may have to disclose your personal information. In addition, it may happen that your information will need to be reviewed by another organisation for quality assurance purposes. I will tell you about this if it happens.

11. **WHAT WILL HAPPEN TO THE RESULTS OF THE RESEARCH STUDY?** The results may be published in a scientific journal. In either case, you will not be identifiable in any documents, reports or publications. You will be given access to the results of this if you would like to see them, by contacting me.
12. **WHAT WILL YOUR RESPONSIBILITIES BE, AS THE RESEARCHER?** My responsibility is to collect, analyse and publish the research findings in a journal and ensuring that your confidentiality is maintained.
13. **WHO IS ORGANISING AND FUNDING THIS RESEARCH STUDY?** The study is being organised by me, under the guidance of my research co-investigator at the Department of Human Anatomy and Physiology at the University of Johannesburg. The study is funded through my research subsidy received from publication of research papers.
14. **WHO HAS REVIEWED AND APPROVED THIS STUDY?** Before this study was allowed to start, it was reviewed in order to protect your interests. This review was done first by the Department of Human Anatomy and Physiology, and then secondly by the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg. In both cases, the study was approved.
15. **WHAT IF THERE IS A PROBLEM?** If you have any concerns or complaints about this research study, its procedures or risks and benefits, you should ask me. You should contact me at any time if you feel you have any concerns about being a part of this study. My contact details are:

Trevor Nyakudya

011 559 6802

trevorn@uj.ac.za/ trevortn@gmail.com

If you feel that any questions or complaints regarding your participation in this study have not been dealt with adequately, you may contact the Chairperson of the Faculty of Health Sciences Research Ethics Committee at the University of Johannesburg:

Prof. Christopher Stein

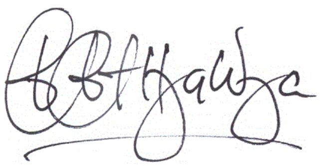
Tel: 011 559-6564

Email: cstein@uj.ac.za

FURTHER INFORMATION AND CONTACT DETAILS: Should you wish to have more specific information about this research project information, have any questions, concerns or complaints about this research study, its procedures, risks and benefits, you should communicate with me using any of the contact details given above.

Researcher:

Dr Trevor T. Nyakudya



Appendix 3C: Research consent form

UNIVERSITY
OF
JOHANNESBURG

DEPARTMENT of Human Anatomy and Physiology

RESEARCH CONSENT FORM

REC 11.0

Students' perceptions of learning threshold concepts in neurophysiology: a qualitative study

Please initial each box below:

☐ I confirm that I have read and understand the information letter dated 15 November 2019 for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.

☐ I understand that my participation is voluntary and that I am free to withdraw from this study at any time without giving any reason and without any consequences to me.

☐ I agree to participate in the above research.

________________________ ________________________________ _________________

Name of Participant Signature of Participant Date

________________________ ________________________________ _________________

Name of Researcher Signature of Researcher Date

Appendix 3D: Consent to the use of an audio tape

UNIVERSITY OF JOHANNESBURG

DEPARTMENT OF Human Anatomy and Physiology

RESEARCH CONSENT FORM OR INTERVIEWS TO BE AUDIO-TAPED

(Please delete this entire page if your research does not involve audio-recording)

Students' perceptions of learning threshold concepts in neurophysiology: a qualitative study

Please initial each box below:

☐ I hereby give consent for my interview, conducted as part of the above study, to be audio-taped.

☐ I understand that my personal details and identifying data will be changed in order to protect my identity. The audio tapes used for recording my interview will be destroyed two years after publication of the research.

☐ I have read this consent form and have been given the opportunity to ask questions.

________________________ _______________________________ _________________

Name of Participant Signature of Participant Date

Name of Researcher	Signature of Researcher	Date

Appendix 4: Interview guide

Main Question

In relation to other Physiology topics that you have covered in the subsequent terms, how did you find neurophysiology?

Prompting Questions

1) Is there any concept that was particularly easy for you to understand? Elaborate
2) Is there any concept that was particularly difficult for you to understand? Elaborate
3) Did you finally understand the concept? How did you manage to understand the concept?

Appendix 5: Consent form

I ______________________________________ hereby agree to participate in the research study on the student perspectives on the learning of neurophysiology threshold concepts.

I understand that my participation is voluntary, I may withdraw at any point from the study. I will be treated fairly and that confidentiality will be maintained throughout the study. My privacy will be protected.

I agree that my participation will remain anonymous YES NO (please circle)

I agree that the researcher may use anonymous quotes

in his research report YES NO

I agree that the interview may be audio-recorded YES NO

I agree that the researcher may take photos of me YES NO

(but not my face)

I agree that the information I provide may be used YES NO

anonymously by other researchers following this study

____________________ ________________

Signature of Participant Date

Appendix 6: Consent to the use of an audio tape

I ______________________________________ hereby give permission to the use of an audio tape-recorder during the interview session.

____________________   ________________

Signature of Participant   Date

Appendix 7: Student Participant Information Sheet for all first year students

Dear prospective participant

My name is Dr Trevor Nyakudya and I am a Masters student in Health Science Education at the University of the Witwatersrand in Johannesburg, Faculty of Health Sciences, Centre for Health Science Education. I am doing a project on finding out the perceptions of students concerning their learning of neurophysiology. The title of the research project is "Students' perceptions of learning neurophysiology at a South African university: a qualitative study"

As part of this project, I would like to invite you to take part in an interview. This activity will involve answering questions and will take around 20-30 minutes. The questions will generally explore your perceptions of learning threshold concepts in neurophysiology. With your permission, I would also like to record the interview using a digital device.

You will not receive any direct benefits from participating in this research, and there are no disadvantages or penalties for not participating. You may withdraw at any time or not answer any question if you do not want to. The interview will be completely confidential as I will not be asking for your name or any identifying information, and the information you give to me will be held securely and not disclosed to anyone else. I will be using a study number to represent your participation in my final research report. If you experience any distress or discomfort at any point in this process, we will stop the interview or resume another time. If you need some support or counselling services following the interview, these are available free of charge at the Centre for Psychological Services and Career Development (Contact number: 011 559 6042)..

If you have any questions during or afterwards about this research, feel free to contact me on the details listed below. This study will be written up as a research report which will be available online through the university library website. If you wish to receive a summary of this report, I will be happy to send it to you. If you have any concerns or complaints regarding the ethical procedures of this study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email Shaun.Schoeman@wits.ac.za.
Yours sincerely,

Dr Trevor T. Nyakudya, 0718789e@students.wits.ac.za, 011 559 6802

Supervisor: Mrs Shirra Moch, Shirra.Moch@wits.ac.za. 011 717 2586

IF YOU ARE WILLING TO PARTICIPATE IN THIS STUDY PLEASE RETURN THE ATTACHED YELLOW FORM TO ME OR E-MAIL ME AT trevorn@uj.ac.za.

YELLOW FORM

Name: ____

E-mail address: ________________________________

Cell Phone number: ____________________________

I would like to participate in the study entitled "Students' perceptions of learning neurophysiology at a South African university: a qualitative study"

Appendix 8: Turn-It-In Score

Research report

ORIGINALITY REPORT

17%	14%	7%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	ujcontent.uj.ac.za Internet Source	4%
2	Submitted to University of Johannsburg Student Paper	2%
3	Submitted to University of Witwatersrand Student Paper	1%
4	wiredspace.wits.ac.za Internet Source	1%
5	Louise A. Horrigan. "Tackling the threshold concepts in physiology: what is the role of the laboratory class?", Advances in Physiology Education, 2018 Publication	1%
6	www.pure.ed.ac.uk Internet Source	1%
7	www.tandfonline.com Internet Source	<1%
8	core.ac.uk Internet Source	<1%

9	wiredspace.wits.ac.za Internet Source	<1 %
10	eprints.lancs.ac.uk Internet Source	<1 %
11	core.ac.uk Internet Source	<1 %
12	Submitted to University of East London Student Paper	<1 %
13	Submitted to Aspen University Student Paper	<1 %
14	Submitted to University of New South Wales Student Paper	<1 %
15	Submitted to University of Pretoria Student Paper	<1 %
16	docplayer.net Internet Source	<1 %
17	uzspace.uzulu.ac.za Internet Source	<1 %
18	www.duo.uio.no Internet Source	<1 %
19	www.europeanproceedings.com Internet Source	<1 %
20	en.wikipedia.org Internet Source	<1 %

21	www.tn.newglarus.wi.gov Internet Source	<1 %
22	Submitted to OTHM Qualifications Student Paper	<1 %
23	archive.org Internet Source	<1 %
24	Ray Land, Jan H.F. Meyer, Jan Smith. "Threshold Concepts within the Disciplines", Brill, 2008 Publication	<1 %
25	Sophie Hill. "The difference between troublesome knowledge and threshold concepts", Studies in Higher Education, 2019 Publication	<1 %
26	mural.maynoothuniversity.ie Internet Source	<1 %
27	Submitted to North West University Student Paper	<1 %
28	Usir.Salford.Ac.Uk Internet Source	<1 %
29	curve.coventry.ac.uk Internet Source	<1 %
30	www.gjcity.org Internet Source	<1 %

Submitted to University of Glasgow