A WORK INTEGRATED LEARNING CONTENT FRAMEWORK FOR CLINICAL NEUROPHYSIOLOGY TECHNOLOGY IN SOUTH AFRICAN UNIVERSITIES OF TECHNOLOGY

Christelle van der Walt

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Dr P M Orton [redacted] **Date:** 1 April 2024
(Supervisor-DUT)

Dr D R Prakaschandra [redacted] **Date:** 15 August 2024
(Co-supervisor – DUT)

Dr S Marais: ____________________ **Date:** __________________
(Co-supervisor – External)

DECLARATION

This study represents original work by the author. It has not been submitted to any other tertiary institution. Where the work by others is made use of, this has been duly acknowledged.

The research described in this dissertation was completed under the supervision of Dr P M Orton and Dr D R Prakaschandra and Dr S Marais in the Department of Biomedical and Clinical Technology, Faculty of Health Sciences, Durban University of Technology.

SIGNED: [redacted]

Ms Christelle van der Walt
(B.Tech: Clinical Technology)

I hereby certify that the above statement is correct.

SIGNED: [redacted]

Dr P M Orton
(PhD Nursing)

SIGNED: ______________________________

Dr D R Prakaschandra
(PhD Clinical Technology)

SIGNED: ______________________________

Dr S Marais
(PhD Neurology)

DEDICATION

I dedicate this work to:

My family. My mother for her unconditional love and belief in me and her incredible support during the process of research and writing. My brother for always having had confidence in my abilities even when I doubted myself, and my father for his legacy of teaching me the value of tenacity and never giving up.

Dr Carl Vogts, my uncle, for his valuable professional and life advice, and Mr Henry Welman, my science teacher, for helping me realise at an early age that I can do anything I put my mind to.

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ABSTRACT

INTRODUCTION

Clinical technology (CT) is a group of seven specialist professions dealing with diagnosis and monitoring of human organ system function and diseases. Clinical neurophysiology (CN) is one of these professions and uses multi-modality test investigations of the brain, peripheral and central nervous system, and muscular system, to diagnose and monitor neurological disease.

Since the origin of formal training, specialist learning in one of these categories has occurred during a period of work-integrated learning (WIL) after a combined didactic period at one of the three South African universities of technology that offer this qualification. The duration of this period has fluctuated over time. Currently this is set at 3 840 hours over a 24-month placement period as per the South African Qualifications Authority (SAQA) course registration documents.

No previous investigations have been conducted to determine the industry required content of this WIL period or how the testing and monitoring modalities taught support specialist learning. No category specific training frameworks exist to aid training units at any of the current three universities offering this qualification.

AIMS AND OBJECTIVES

The purpose of this study was to determine the current industry requirements for graduates to integrate into Clinical Neurophysiology private practice upon graduation. This study aimed to determine the core testing modalities to include in an undergraduate clinical technology qualification and how each modality can support learning of related modalities. Related to this, this investigation also aimed to determine embedded skills, knowledge, and personal graduate attributes required for mastering of each of the core modalities.

The final objective was to design a learning framework based on the interconnected learning affinity of modalities that incorporates all the required graduate skills that drive achievement of graduate level outcome skill levels as determined by industry requirements.

METHODOLOGY

A Delphi research study was designed to firstly investigate the historic development of the profession and training, and secondly determine the core testing modalities and related knowledge and skills a current industry aligned qualification should include.

A round of unstructured interviews and desk research was undertaken to identify all modalities currently included in university of technology course documents. A total of 23 modalities were identified. This round of data gathering was followed by two Delphi questionnaires.

The first questionnaire (Q1) provided clinical neurophysiologists (CNPs) currently in private practice an opportunity to select their preferred core modalities from the list of modalities identified during the first data gathering round. Participants were also able to contribute current industry required outcome skill levels and embedded skills and knowledge required to master each modality. Fifty participants identified a list of 15 modalities as potential core modalities and contributed approximately 1 600 comments on prerequisite skills and embedded knowledge and graduate attributes.

The second questionnaire (Q2) reported the findings of the first and provided the 36 participants with the opportunity to evaluate the learning and prerequisite dependence or affinity of interrelated modalities. The participants also reevaluated the required outcome practice skill level for each modality and how knowledge and practical skills from Q1 drive learning of the core modalities.

RESULTS

At the end of the second questionnaire a total of 13 modalities were identified as core modalities that are essential to master during undergraduate WIL. It was determined that students must be able to perform, report, and interpret the results of the 13 core modalities.

Dependence affinity of the 13 core modalities for learning of related modalities was confirmed and the embedded and prerequisite skills driving the mastering of each modality were combined into a learning framework. Results confirmed the historic foundational importance of electroencephalography (EEG) as a prerequisite to learning all the other core modalities.

CONCLUSION

This was the first study investigating industry required graduate outcome skills for an undergraduate qualification in clinical technology. Through a Delphi study 13 core outcome modalities were identified and the required outcome skills level for integrating into private practice was determined. Participant skills and knowledge contributions were drawn upon to design a driver-based learning framework that can guide the universities and training units in structuring the WIL period for most efficient clinical training time management to achieve the required graduate skills outcomes during the 3 840 clinical training hours.

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LIST OF ACRONYMS

AAET	American Association of Electrodiagnostic Technologists
ABRET	American Board of Registered Electroneurodiagnostic Technologists
ANSA	Association of Neurophysiology Scientists of Australia (Alternate name: Association of Neurophysiological Technologists of Australia)
ANTA	Association of Neurophysiological Technologists of Australia (Alternate name: Association of Neurophysiology Scientists of Australia)
ASET	American Society of Electroneurodiagnostic Technologists (Alternate name: ASET – The neurodiagnostic society)
ASET	ASET – The Neurodiagnostic Society (Alternate name: American Society of Electroneurodiagnostic Technologists)
B Tech	Bachelor of Technology
BAEP	brainstem auditory evoked potential (modality)
BRECTS	benign Rolandic epilepsy with centro-temporal spikes (Childhood self-limiting epilepsy syndrome)
BRPT	Board of Registered Polysomnographic Technologists
BHS	Bachelor of Health Science
CBM	cortical brain mapping (modality)
CBT	competency based test
CHE	Council for Higher Education
cICU	continuous ICU electroencephalography (modality)
CI	confidence interval for the mean
CIDP	chronic inflammatory demyelinating polyneuropathy
CN	clinical neurophysiology (profession)
CNP	clinical neurophysiologist
CNSSA	Clinical Neurophysiology Society of South Africa
CN-T	clinical neurophysiology technologist
CNT	clinical neurophysiology technology (field of study)
COV	coefficient of variation
CPAP	continuous positive airway pressure (alternate name: non-invasive ventilation positive airway pressure)
CT	clinical technology
CUT	Central University of Technology

DBS	deep brain stimulation (modality)
DoN	Division of Neuropsychology
DUT	Durban University of Technology
EE	EEG technician
EEG	electroencephalography/electroencephalogram (modality)
EMG	electromyography/electromyogram (modality)
EP	evoked potential (modality group)
EDS	excessive day time sleepiness
FVEP	flash visual evoked potential (modality)
HoD	Head of Department
HFVAH	Hendrik Verwoerd Academic Hospital
HPCSA	Health Professions Council of South Africa
IALCH	Inkosi Albert Luthuli Central Hospital
ICU	intensive care unit
IOM	intraoperative monitoring (modality group)
IONM	intraoperative neuromonitoring (modality)
KT	clinical technologist
KTG	clinical technologist – graduate
KT-S	clinical technology student
LTEM	long-term EEG monitoring (modality)
LTM	Long-term monitoring (modality group)
M Tech	Master of Technology
MSLT	multiple sleep latency test (modality)
MT	memory testing (modality)
MWT	maintenance of wakefulness test (modality)
N Dip	National Diploma
NDT	neurodiagnostic technology
NCS	electroneurography (alternate name: nerve conduction study)
NCS	nerve conduction studies (modality)
NHS	National Health Services
NIPR	National Institute for Personnel Research
NIV PAP	non-invasive ventilation positive airway pressure (modality) (alternate name: continuous positive airway pressure)
NM	neuromuscular (modality group)

OSA	obstructive sleep apnoea
OSCE	objective structured clinical examination
OSL	outcome skill level
OtJT	on the job training
PA	percentage agreement
PANRM	percentage agreement with the non-rounded mean score rating
pers. comm.	personal communication
PjBL	project-based learning
PNUS	peripheral nerve and muscle ultrasound (modality)
PRVEP	pattern reversal evoked potential (modality)
PSG	polysomnography (modality)
Q1	Questionnaire 1
Q2	Questionnaire 2
QP	QuestionPro®
RCT	Board of Radiography and Clinical Technology (of the HPCSA)
RAA	respondent anonymity assurance®
SAMDC	South African Medical and Dental Council
SAQA	South African Qualifications Authority
SAVKT	Suid Afrikaanse Vereniging van Kliniese Tegnoloë
SD	standard deviation of the mean
SE LTEM	LTEM using surface electrodes (modality)
SG LTEM	LTEM with subdural grid electrodes (modality)
SSEP	somatosensory evoked potential (modality)
TBH	Tygerberg Hospital
TCD	echoencephalography (alternate name: transcranial Doppler)
TCD	transcranial Doppler (modality)
TLA	teaching, learning, and assessment
TOFS	Technikon Orange Free State
TUT	Tshwane University of Technology
UK	United Kingdom
UKZN	University of KwaZulu-Natal
UoT	university of technology
US	ultrasound (modality group)
USA	United States of America

VEP	visual evoked potentials
WADA	WADA test (modality)
WBL	work-based learning (alternate name: workplace learning)
WEL	work experiential learning
WIL	work integrated learning
WITS	University of the Witwatersrand

DEFINITIONS AND TERMINOLOGY

1. Work integrated learning (WIL)

The term work integrated learning and abbreviation WIL is used as an umbrella term inclusive of multiple modes of teaching and learning in a professional work environment where theory and practice is combined. Where appropriate further details on the numerous types of teaching and learning subtypes were provided (see Section 2.6.).

2. Work experiential learning (WEL)

Prior to the introduction of the Bachelor of Technology (B Tech) qualification National Diploma (N Dip) graduates were required to perform a period of supervised practice prior to registration as a qualified clinical technologist. The term work experiential learning and abbreviation WEL is used to represent this period of compulsory training time (Section 1.3 and Section 1.4.).

3. Competency versus Proficiency

Competency was considered as the ability to perform a task well, whereas proficiency was considered the ability to also understand and evaluate the results of the completed task (Roberts *et. al.* 2024). These terms were applied to differentiate between outcome practice skill levels and graduate level outcome skills (Section 3.13.3.2).

4. Outcome practice skill levels and graduate level outcome skills

Graduate level outcome skills were determined as the final level of skill a graduate must master for ability to practice their profession independently. Outcome practice skill levels (OSL) were defined as subcategories of progressive practice abilities such as ability to perform a procedure versus the ability to analyse the results (Sections 3.11.3.1 and 3.11.4.1.3.).

5. Embedded skills

It was considered that each of the final test modalities would require overlapping practical and graduate skills to facilitate learning and mastering. These embedded skills were differentiated as either practical, theoretical, or graduate attribute skills. Individual skills were contributed by questionnaire one participants and reviewed for relevance and importance by questionnaire two participants. Embedded practical and theoretical skills were tested in relation to individual test modalities, whereas graduate personal attribute skills were tested in relation to practicing as an independent graduate clinical neurophysiologist.

CHAPTER 1: INTRODUCTION

This chapter describes the industry and training background against which the rational for this study developed over time. It will orientate the reader to the South African context of the profession of Clinical Technology (CT) and familiarise the reader with how past and current training in Clinical Neurophysiology (CN) relates to current industry professional practice needs.

1.1 Development of clinical technology

On 18 September 1975 the Suid Afrikaanse Vereeniging van Kliniese Tegnoloë was established. At this first meeting Clinical Technology was defined as a group of specialist category professions dealing with physiological testing and monitoring of human organ systems using technology and the name Clinical Technologist (KT) was chosen to represent the persons performing these professions. (SAVKT 1982, 1995; Human 1996).

Since the development of the first training course in CT, and subsequent recognition of the profession by the South African Medical and Dental Council (SAMDC), category specialisation occurred during a period of work integrated learning (WIL). Despite two post graduate studies dealing with assessment of CT students (KT-S) in aggregate no research has been conducted in the delivery of WIL and no evidence of standardised category specific WIL frameworks were found in the literature reviewed (Human 1996; Mohapi 2017). Only one publication, focusing on the category of perfusion, reviewed CT educator perceptions of training programs in South Africa (Ali-Musa *et al.* 2018).

Currently the Health Professions Council of South Africa (HPCSA), the Council for Higher Education (CHE) and the Department of Higher Education and Training recognise seven independent and diverse health professions as specialist categories under the umbrella of CT (South African Qualifications Authority [SAQA] 2012). At the HPCSA CT is regulated by the Professional Board of Radiography and Clinical Technology (RCT). The RCT is responsible for the development and monitoring of both the CT scope of profession and clinical scope of practice of each specialist category.

1.2 Clinical neurophysiology as a profession

The field of study of clinical neurophysiology technology (CNT) sprouted its multiple additional modalities from the original electroencephalography (EEG) certificate course first developed by the National Institute for Personnel Research (NIPR) under the Council for Scientific and Industrial Research. During the late 1970s to the early 1980s, various centres around the country started performing evoked potentials (EP), electromyography (EMG) and electroneurography which is now referred to as nerve conduction studies (NCS). This occurred at roughly the same time as the formation of the first Professional Board of Clinical Technology. Clinical neurophysiology (CN) units at academic hospitals in Cape Town and Durban flourished, notably Tygerberg Hospital (TBH) with Mr L van Niekerk, Mr D Claasen and Mr G Hart; Wentworth Hospital in Durban with Mr L Marais; HF Vervoerd Academic Hospital (HFVAH) in Pretoria with Professor P Bartel and Mrs Elna Janse van Rensburg (née Robinson), all of whom were involved in the first professional society and board (per. comm. Professor Bartel, past Head of Department [HoD] CN HFVAH October 2019; Professor Bill, first HoD Neurology, University of KwaZulu-Natal [UKZN] and Mr Hans Human, member of the first professional society training committee, February 2020).

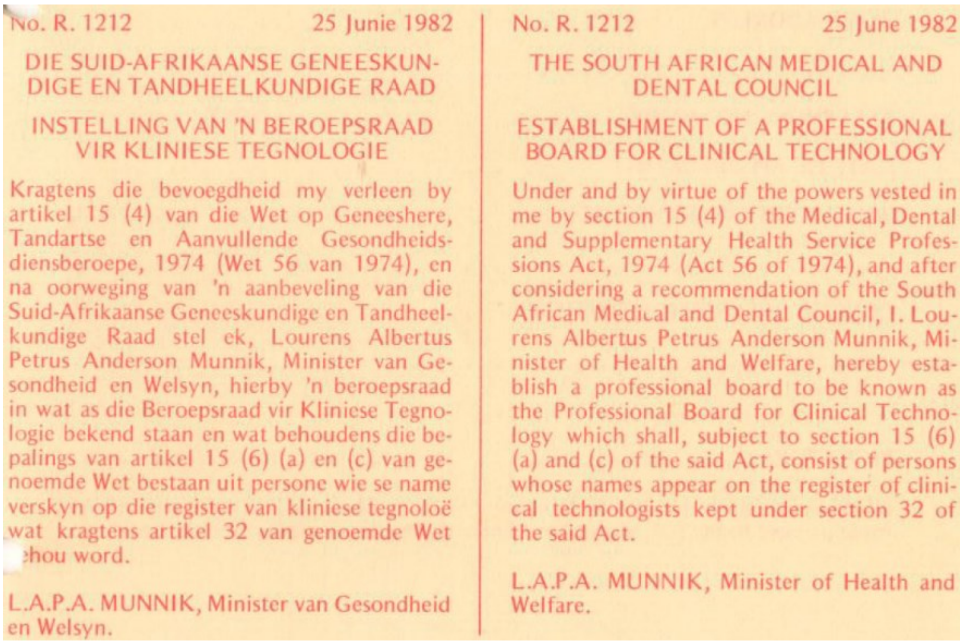
Development of the first qualification in CT followed shortly with incorporation of these complementary testing modalities into the Technikon based CT National Diploma (N Dip) qualification (Professional Board for Clinical Technology 1986).

The first KTs specialised in CNT were recognised by the SAMDC in 1980 with the establishment of the first professional board in 1982 (Figure 1.1) (South Africa 1982; Suid-Afrikaanse Vereniging van Kliniese Tegnoloë [SAVKT] 1982).

Clinical neurophysiology technology in South Africa developed from EEG, and the first formal EEG education was offered by the NIPR in Johannesburg, a programme that Professor (emeritus) Peter Bartel was closely involved in and where his career as a clinical neurophysiologist (CNP) started (2019, pers. comm. 09 October).

The initial N Dip examinations in CNT during the early 1980s consisted of mainly EEG and a limited range of NCS, and visual EP (VEP) studies (pers. comm. Professors Bartel 09 October2019 and Pieterse, retired HoD CT at TUT, 10 October 2019). The first scope of practice document however made provision for a much wider area of practice (Figure 2.1). Only during the late 1980s and toward the development of the Bachelor of Technology degree (B Tech) in the early 1990s did the course assessments grow to officially include multimodality EPs and polysomnographic (PSG) sleep investigations (pers. comm. Professor P Bartel, 09 October 2019).

The 2012 permutation of the B Tech (South African Qualifications Authority [SAQA] 2012), and current Bachelor of Health Science (BHS) (SAQA 2018), qualifications now list eleven specialist outcome procedures for CN that can be grouped into eight major modality groups and divided into a total of 23 individual test modalities (Table 2.5) (SAQA 2012).



No. R. 1212 25 Junie 1982

DIE SUID-AFRIKAANSE GENEESKUNDIGE EN TANDHEELKUNDIGE RAAD

INSTELLING VAN 'N BEROEPSRAAD VIR KLINIESE TEGNOLOGIE

Kragtens die bevoegdheid my verleen by artikel 15 (4) van die Wet op Geneeshere, Tandartse en Aanvullende Gesondheidsdiensberoepe, 1974 (Wet 56 van 1974), en na oorweging van 'n aanbeveling van die Suid-Afrikaanse Geneeskundige en Tandheelkundige Raad stel ek, Lourens Albertus Petrus Anderson Munnik, Minister van Gesondheid en Welsyn, hierby 'n beroepsraad in wat as die Beroepsraad vir Kliniese Tegnologie bekend staan en wat behoudens die bepalings van artikel 15 (6) (a) en (c) van genoemde Wet bestaan uit persone wie se name verskyn op die register van kliniese tegnoloë wat kragtens artikel 32 van genoemde Wet gehou word.

L.A.P.A. MUNNIK, Minister van Gesondheid en Welsyn.

No. R. 1212 25 June 1982

THE SOUTH AFRICAN MEDICAL AND DENTAL COUNCIL

ESTABLISHMENT OF A PROFESSIONAL BOARD FOR CLINICAL TECHNOLOGY

Under and by virtue of the powers vested in me by section 15 (4) of the Medical, Dental and Supplementary Health Service Professions Act, 1974 (Act 56 of 1974), and after considering a recommendation of the South African Medical and Dental Council, I, Lourens Albertus Petrus Anderson Munnik, Minister of Health and Welfare, hereby establish a professional board to be known as the Professional Board for Clinical Technology which shall, subject to section 15 (6) (a) and (c) of the said Act, consist of persons whose names appear on the register of clinical technologists kept under section 32 of the said Act.

L.A.P.A. MUNNIK, Minister of Health and Welfare.

Figure 1.1: Notice regarding establishment of the first board for clinical technology
Source: SAVKT (1982)

1.3 Development of training in South Africa

As mentioned above, initial training was needs-based during the post war period, and only in the late 1970s was formal recognition of the profession sought.

The need for formalised training was industry driven and Technikons were co-opted to offer structured and standardised learning.

The first N Dip course consisted of a year of combined didactic teaching followed by two years of category specific WIL and a subsequent 12 months of or work experiential learning (WEL), before registration as a qualified clinical technologist (KT) i.e., three years of practical experience.

This was followed by a second iteration of the N Dip which increased the didactic period to two years and decreased the WIL period to one year. This was then followed by two years internship, or WEL, before professional registration. The post didactic experience period remained three years.

Subsequently a four-year degree course was developed to build upon the existing three-year N Dip. A one-year fulltime or two-year part-time B Tech qualification replaced the two years post N Dip WEL.

Since 2019 education and training in CT were once again restructured, this time to a four-year BHS degree.

This current BHS qualification includes two years of full-time on campus theoretical didactic education, followed by two years combined theoretical and clinical work-based learning at an academic clinical training unit. This was initially planned to be followed by a 12-to-24-month supervised practice WEL period before RCT registration as private or independent practitioners.

The BHS was originally structured for WIL to happen in conjunction with increased theoretical on-campus instruction during the third- and fourth-year enrolment. The 2020 international COVID-19 pandemic and restrictions on group gatherings forced each university of technology (UoT) to institute some type of distance lecturing system resulting in a shift to online lectures during study year three and four.

In addition, the previously proposed post-graduation internship period before gaining private practice registration was removed at the beginning of 2020. This comes as the HPCSA RCT started restructuring practice registration requirements. In effect a KT-S that now graduates must obtain the same skills and abilities in as little as 18 months of clinical WIL instruction compared to the 24-month supervised practice WEL period that was expected of pre 2002 N Dip graduates after completion of 12 months WIL (representing a combined three-years of practical training).

Once again, a disconnect between universities was seen with some choosing to provide lectures of up to ten hours per week for third year KT-S during work hours, while others limited lectures to seven hours per week, with most classes occurring after typical work hours (personal experience in our unit with two UoT programmes).

Despite the perceived insufficiencies, CNT KT-S in the B Tech, which is being phased out, felt overwhelmed with the scope of specialist subject content, and breadth of skills, required for graduation of N Dip and B Tech. This is a sentiment that was echoed by the first group of CNT KT-S enrolled in the new BHS degree at both the Durban University of Technology (DUT) and the Tshwane University of Technology (TUT) (personal experience as clinical instructor, tutor, and part-time lecturer for DUT and TUT).

Individual university course delivery and assessment structures also further diversified between 2020 and 2021 with TUT opting to retain a third-year university managed final competency-based test (CBT) in at least five of the practical modalities, whereas DUT continued with continuous practical assessment in the units and periodical marks submissions. University involvement was limited to the theoretical examinations and final objective structured clinical examination (OSCE) examination, but little other involvement in skills development during WIL training.

1.4 Registration with professional board

Initial professional registration as a CT was based on experience. With the development of formal education, achievement of the N Dip and WEL became compulsory for registration with the SAMDC.

Until the development of the B Tech qualification candidates would be registered as KT-S until completion of a three-year N Dip and requisite 24-month WEL internship period. At the fulfilment of these requirements candidates were registered as independent KTs.

With the inception of the B Tech this optional additional qualification replaced the requirement of WEL and the newly formed HPCSA RCT developed separate registration categories. A distinction was made between diplomates possessing a three-year N Dip and those who also obtained the B Tech. Clinical Neurophysiology Technologists (CN-T) holding only a N Dip was registered under supervised practice whereas those with a B Tech would be registered as private practice. With the new

BHS qualification, the need for the supervised practice distinction between N Dip and B Tech graduates has fallen away and all BHS graduates will directly be recognised as an independent practice graduate clinical technologist (KTG). Furthermore, the requirement for a distinction between supervised practice and independent practice in industry is no longer needed as all new graduates exiting training units will once again be eligible for independent private practice. As a result, in 2021, the RCT decided to close the private practice register and announced that the private practice and independent practice registers would be consolidated, and all practitioners' status would revert to independent practice (Health Professions Council of South Africa Corporate Affairs 2021).

At the start of 2022 the only names on the supervised practice register were N Dip qualified technologists that missed the deadline, or chose not to complete a B Tech qualification, prior to the end of the registration date.

1.5 The role of work integrated learning

WIL forms the basis of the specialisation in all seven CT categories. According to Engel-Hills *et al.* (2010), work integrated learning (WIL) can be described as an educational approach that aims to align workplace practice and academic needs to the mutual benefit of the workplace and students. However, WIL is an umbrella term that describes several modes of integrated practical and theoretical learning pedagogical methods. The most commonly thought of modes are arguably workplace learning, also called work-based learning (WBL) and work experiential learning (WEL).

The aim of all modes of WIL is to facilitate student learning and preparedness for their career work environment. The inclusion of a strong emphasis on WIL during specialisation in CT is reflective of this principle. However, it is also important to realise that not all WIL is the same and careful decisions need to be made when choosing one or more approaches or modes of learning.

1.6 Concerns and expectations regarding training outcomes

Industry expects KT-S in the new BHS to reach at least the same practical skills and specialist category knowledge, in an ill-defined group of critical skills, as B Tech graduates with private practice registration (Clinical Neurophysiology Society of South Africa [CNSSA] 2018). This clinical proficiency is expected to be achieved while the non-category specific academic course content has increased, and the clinical WIL or WBL time has decreased (Durban University of Technology 2015).

In this last permutation of CT education, CNT clinical learning time has decreased from the original four years, complemented by one-year didactic education, to as little as 18 months in a four-year period. With the drastic decrease in clinical training the time has come to investigate a formalised category specific training framework for CNT. This framework would aim to prepare our KT-Ss to function independently in the South African public as well as private practice environment directly post-graduation.

The vastly differing assessment and outcomes monitoring between universities and clinical training units is perceived to have increased, with a concomitant increase in industry concern about the quality and abilities of BHS graduates.

This anxiety was demonstrated by the industry application to RCT to implement an internship period after registration, prior to graduates being able to practice in their own solo capacity; at the 2019 year-end RCT stakeholder meeting a two-year period was announced.

This decision was however overturned in 2020 with graduates registering for independent solo practice upon graduation. This decision caused much concern in the industry.

According to information provided by the RCT during the 2022 annual stakeholders meeting (Online 24 May 2022) clinical neurophysiology technologists (CN-Ts), or CNPs, comprised roughly 10% of the registered KTs between 2017 and 2021. Training needs and the impact of changes in course structures have never been investigated in CNT. Clinical neurophysiology technology as a separate field of study is often overlooked, a fact that poses multiple training challenges as the number of sub-speciality testing modalities included in the current industry scope of CN has grown exponentially in the last three decades. In response to this growth in CNT and other categories the RCT has been in the process of reviewing both the CT "Scope of Profession" document encompassing all categories, and the category specific "Scope of Practice" regulations between 2019 and 2021 and finalisation was expected mid-2022. This review and update is again an indication that the WIL offering should also be reviewed to ensure that graduates are capable of fulfilling their RCT defined roles upon registering with the HPCSA.

1.7 Aims, objectives and the main research questions

The primary aim of this study was to explore and describe the core CNT modality competencies, and imbedded prerequisite skills and attributes, required of a CNT graduate, and to propose a standardise WIL content framework for the BHS degree. The objectives of the study were explorative and are summarised in Table 1.1.

Table 1.1: List of objectives

	Objectives
1	Explore and describe the core neurophysiological modalities
2	Explore and describe related knowledge, and embedded skills required of a CN graduate
3	Explore and describe the core industry expected minimum required practical and theoretical skills
4	Develop a standardised WIL content framework for the BHS CNT in South Africa

This study investigated, and clarified, through searching for existing industry consensus, how a CNT WIL training programme should be structured around standardised core procedures in the fulfilment of the requirements of industry which will enable BHS graduates to integrate into industry as independently practicing CNPs immediately upon graduation. The research questions used for this investigation are summarised in Table 1.2.

Table 1.2: Research questions

	Research Questions
1	What are the core clinical modalities required of a BHS graduate in CNT in South Africa?
2	What are the embedded skills required for each core modality required of a BHS graduate in CNT?
3	What are the components of a standardised WIL framework for the BHS CNT in South Africa?

1.8 Rationale

Since the 1990s CNT, as part of CT, has followed the same prescribed model of learning, consisting of two years didactic on campus teaching, followed by a one-year

WIL period in an accredited clinical training unit to earn the N Dip qualification. This would then ideally be followed by either one or two years of additional experience under the supervision of a KTG while completing the B Tech degree. However, the B Tech model meant that diplomate technologists could complete the B Tech qualification while under the supervision of a medical specialist and without the additional specialist training a KTG would have been able to provide.

It is during WIL in accredited clinical training units that specialisation is achieved. Both teaching and assessments during this time are left to the WIL units for N Dip, and the supervisory KTG for B Tech. No national standardised training curriculum or exit-level proficiencies have been delineated for CNT for either N Dip or B Tech (Human 1996).

Ali-Musa *et al.* (2018: 1) found that, according to educators, perfusion education is "plagued with lack of standardised curriculum, study outcomes and competencies". Their study concluded education should be standardised and that a national single exit examination should be required.

Since the introduction of computerised equipment during the late 1980s, electroneurodiagnostic technologies have expanded exponentially. New testing modalities have been developed, and advanced application of old modalities have emerged. In a study relating to neurodiagnostic skills training in North America. Dr Marsh-Nation found 70 skills, including technical and "soft" skills, pertaining to EEG alone (Marsh-Nation 2019).

In South Africa the prescribed WIL training for a qualification in CNT consists of a combination of investigations including EEG, NCS and EMG, EP, sleep studies (PSG, MSLT, maintenance of wakefulness test [MWT]), and transcranial Doppler blood flow investigations (TCD).

Despite being part of the South African Qualifications Authority (SAQA) document, only one WIL unit routinely performs and provides training in the performance of TCD. No academic units offer training in brain mapping and subdural monitoring.

South African authors van der Walt, Thomas and Figaji (2013: 197) stated that "intraoperative neurophysiological monitoring is fast becoming the gold standard in specialised neurosurgical and spinal centres throughout the world". However, training in this modality of CNT is not part of the basic training requirements for undergraduate

WIL or listed in the SAQA qualification outcomes for neurophysiology (SAQA 2012). A 2019 CN industry meeting to discuss training for intraoperative neuromonitoring (IONM) indicated that a post graduate qualification would be more desirable than trying to include the growing field in the new course design. It is therefore evident that not only do our current WIL models not have standardisation across South Africa, but the training does not fulfil either the published SAQA qualification specifications or the current industry needs.

1.9 Conclusion

At the origin of our profession in South Africa, the technikons, early industry practitioners, and original clinical units, worked together to formalise training and achieve recognition of a new group of professions under the umbrella of CT.

In the last four decades this coordination between education, practice, and regulation has been lost. Industry has grown exponentially, while education has undergone restructuring without true change, or industry involvement, and work toward updating regulation of category specific scope of practice documents were still in process during the first half of 2022.

The foundation of CT specialisation in CNT has always been WIL and industry needs to be consulted in the process of building of a new WIL framework for clinical training around industry requirements to ensure the competency of graduate CNPs to integrate into industry immediately upon graduation.

CHAPTER 2: LITERATURE REVIEW

This section will provide an overview of the development of CT and, in more detail, CNT, in South Africa.

The development of the South African training programme will be discussed in the context of the international training environment.

Comments on and review of methods of WIL will be made in relation to its applicability to healthcare and CN training, both nationally and internationally.

2.1 Clinical technology as a profession in South Africa

Little information is available on the development of CT in South Africa and no written record exists of the development of CNT in South. Human (1996) in his Master of Technology (M Tech) thesis did, however, record an abbreviated history of the profession of CT in South Africa. Mr Human was one of the first pulmonology technologists and served as training committee chair for the SAVKT and was a member of the first professional board of SAMDC (Human 1996).

In 1975 representatives of five categories of technology orientated paramedical services (allied health) gathered in Cape Town to seek consensus for naming their combined professions. The meeting was held on 18 September 1975 and was the first meeting of the Suid-Afrikaanse Vereniging van Kliniese Tegnoloë (SAVKT) / South African Society of Clinical Technologists (SAVKT 1995; Human 1996).

These professions were connected through the use of technologically advanced equipment to test and monitor various human organ systems. The name ‘clinical technology’ was accepted as being sufficiently descriptive of the class of medical services provided by these professionals (Human 1996). At this meeting five sub-speciality categories were defined according to the organ systems involved. These were cardiology, cardiovascular perfusion, pulmonology/lung function, nephrology, and CNT as the initial five specialist categories of CT. Two additional categories, critical care and reproductive technology, were subsequently included (Professional Board for Clinical Technology 1986; Human 1996).

The SAVKT successfully petitioned the SAMDC for recognition of this newly defined profession. The first register of CT practitioners was formulated in 1980 and the first five categories of clinical technologists (KTs) were formally registered in 1981 (SAVKT 1982; Health Professions Council of South Africa Corporate Affairs 2021). Initially these KTs primarily consisted of existing practitioners with five to seven years of experience. With the development of the first National Diploma (N Dip), a targeted tertiary education became compulsory (South Africa 1995).

The SAVKT worked closely with the then technikons (later universities of technology) to achieve recognition of the profession and formalise training. In cooperation with several technikons a three-year N Dip qualification was developed following the format of the existing laboratory technician qualification (Human 1996) (Pers. Comm Professor J Pieterse, past HoD CT Pretoria Tegnikon / Tshwane University of Technology [TUT]; Professor P Bartel, past HoD CN HFVAH and University of Pretoria [UP], 10 October 2019). The first KT-S were enrolled in 1978 and graduated in 1981 (Pers. Comm. with Mr H Human, chair of the first SAVKT education committee and author of M Tech thesis "Die geldigheid van prestasie-evaluering van kliniese tegnologie studente" 10 February 2020; Mrs J Verster [CNP in private practice, one of the first CNT graduates from the Pretoria Tegnikon], Professor P Barter past HoD CN HFVAH, 11 October 2019, Professor Pieterse former HoD CT TUT, 09 October 2019).

This history shows the close cooperation between the profession and the education institutions from the onset four decades ago.

2.2 History of clinical neurophysiology in South Africa

The first modality to be introduced into South Africa was EEG as a tool for psychometric assessment.

Professor Bartel credits Mr L van Niekerk, first national secretary of the SAVKT 1982 and his colleagues at TBH, for imagining the profession of CN which opened a new career to candidates limited to the EEG technicians' training. Professor Peter Bartel and Mrs Elna Janse van Rensburg joined the Cape Town technologist as representatives of CN (pers. comm. Professor P Bartel October 2019 and June 2023; pers. comm. Mr H Human 2019; SAVKT 1982; Human 1996).

The first CN specific professional representation was then also the South African EEG Society which later became the Kliniese Neurofisiologie Vereeninging. More recently, the CNSSA was formalised in 2009 and held its first annual congress in 2010.

Since then, the society has been engaging with education and regulatory stakeholders on both practice and education matters. In 2022 CNSSA was formally registered as a not-for-profit organisation.

To obtain further information regarding the development of the profession and training, living pioneers in CT and CNT were interviewed to gather further insight into the history of the current diverse profession of CN.

2.2.1 Introduction of neurophysiology modalities to South African medical practice

The first written record of EEG being used in South Africa was at the NIPR which was established under Professor S Biesheuvel in April 1946 following the end of World War II (Van Ommen and Painter 2008; The Histories Project 2015: 355). Professor P Bartel credits Dr Kooy, a neuro-psychiatrist, for launching the first clinical diagnostic EEG service at Groote Schuur Hospital in 1949 (Bartel 2023). However, the largest influence in development of training was that of the NIPR. The purpose of the NIPR was the study of applied personnel psychology to assist in the process of post-war reconstruction and industrial development in South Africa. Initially the unit was named National Bureau of Personnel Research under the umbrella of the Council for Scientific and Industrial Research. Within two years, under leadership of Professor Biesheuvel, the unit proved viable and was upgraded in status as an independent unit (Anon 1991; The Histories Project 2015). One of the research tools used was EEG in the search for a relationship between brain rhythms, personality, and intelligence. In 1949 Alistair Mundy-Castle, a young psychologist, joined the NIPR and under Professor Biesheuvel established the Division of Neuropsychology (DoN) which housed the first EEG laboratory in Johannesburg (Van Ommen and Painter 2008; Mundy-Castle 2016: 355). Mundy-Castle spent two years in London training in EEG and CN after graduation before coming to Johannesburg. In 1953 he obtained his PhD in Neuropsychology from the University of the Witwatersrand (WITS) for his research into the relationship between personality and EEG rhythms (Mundy-Castle 2016). Focus later included physiological effects of stress and EEG was used as part of air force pilot and navy diver and submariner selection. As the use of EEG expanded neuropsychologist Dr Bruce Murdoch, who headed the Neuropsychology unit between 1975 and 1993 (Van Ommen and Painter 2008: 355), developed a formalised comprehensive EEG technicians' training course during the late 1960s to early 1970s. This course was administered by the DoN between 1972 and 1980. Around 1980 a committee consisting of Drs Bruce Murdoch, John Fleming, Mrs Elna Janse van Rensburg, Mrs Renee Kowalsky and Professor Peter Bartel devised a syllabus to enable distance learning in EEG. Responsibility for examination was handed to the SAMDC and later the HPCSA (pers. comm. Professor Bartel October 2019 and May 2023; pers. comm. Mr P Vermaak October 2019).

Professor Bartel joined the NIPR DoN EEG programme during the mid-1960s. After receiving EEG training, he, together with a psychiatrist, Dr Colin Shapiro, became involved in sleep staging during the 1970s. This was the first confirmed electrographic sleep assessment in South Africa. The focus was on sleep changes and effect on psychometrics. The addition of breathing event monitoring and development of diagnostic polysomnography (PSG) only developed later. Dr Shapiro established the first dedicated diagnostic sleep laboratory at WITS. Diagnostic PSG was being recorded at both HFVAH and TBH in Cape Town since the early 1980s. The first brainstem auditory evoked potential (BAEP) and visual evoked potentials (VEP) were recorded at the DoN by Dr Dev Griesel and Professor Bartel (Van Ommen and Painter 2008: 355). Professor Bartel also performed the first pattern reversal evoked potentials (PRVEP) in 1978 while working at the DoN (personal communication [per. comm.]; Professor Peter Bartel, Head of CN Unit at Steve Biko Academic Hospital (SBAH), 05 October 2019 and 10 October 2019; written confirmation from Professor Bartel May 2023). Until 1973 the DoN was responsible for all EEG training in South Africa, including neurologists. Until its closure in 1993 the DoN was responsible for EEG training of all Gauteng based neurology registrars (Van Ommen and Painter 2008: 356).

Professor Bartel was one of the first CN-Ts whose prior experience in the field was recognised by the SAMDC in 1981 (Health Professions Council of South Africa 2023c). He was subsequently registered by the professional board as a CT from 21 September 1981.

In 1981 Professor Bartel was tasked with starting the CN Unit at HFVAH in Pretoria. He was joined by Ms Elna Janse van Rensburg. Mrs Janse van Rensburg completed the NIPR EEG certificate in 1975 during her time in the South African National Defence Force. She was responsible for recording EEGs as part of the pilot selection process for the Institute for Aviation Medicine. Mrs Janse van Rensburg then went for EP training in the United States of America (USA) before joining HFVAH. Together they recorded the first somatosensory evoked potentials (SSEP) at the HFVAH unit. Mrs Janse van Rensburg was formally registered as a KT on 09 February 1981 (Health Professions Council of South Africa 2023b). This unit became one of the first accredited training facilities for CNT. Both served at the unit until retirement.

Dr Hyam Isaacs was a physician at WITS where he pioneered EMG in South Africa and went on to define the Isaacs Syndrome in 1961 (Isaacs 1961). Nerve conduction studies (NCS) and EMG were introduced to South Africa via several neurology departments during the late 1970s and early 1980s. Professor Kees van der Meyden (neurologist), and Dr Stan Brighton (physician) started EMG at HFVAH (pers. comm: Professor P Bartel 2019; May 2023). According to Mr Peet Vermaak (a CNP in private practice), Professor Lotz continued Professor van der Meyden's training of neurology registrars and CN-T and KT-S at HFVAH in Pretoria in EMG and NCS during the 1980s (pers. comm. 11 October 2019). During this time independent EEG/EMG/NCV services were started at other prominent medical faculties across the country. This included Baragwanath Hospital in Johannesburg under the auspices of WITS internal medicine neurology division under the leadership of Professor Lotz and later Professor Bill (per. comm. with Professor Bill, first HoD of Neurology at the UKZN and former Head of Neurology at Greys Hospital Pietermaritzburg, 05 February 2020). At the same time as the HFVAH unit, the TBH neurophysiology laboratory was formalised and staffed by Mr G Hart and Mr Darrel Claasen. Mr Darrel Claasen motivated for the first EP testing equipment at TBH in 1988 and developed protocols for SSEP and PRVEP testing in collaboration with the HFVAH unit (per. comm. with Mr Claasen January 2014; personal; work experience at TBH; and Professor P Batel October 2019).

Professor Bill introduced NCS and EMG to KwaZulu-Natal when he joined UKZN as first HoD of the new Department of Neurology. The existing EEG laboratory at the Wentworth Hospital psychology and psychiatry department in Durban was then absorbed into the clinical domain of Neurology (pers. comm: Professor Bill February 2022; Professor VB Patel current HoD Neurology UKZN, December 2019). The first KT was Mr Louis Marais who also started a TCD service (per. comm. with Professor Bill February 2022; Professor VB Patel current HoD Neurology UKZN, December 2019). This unit was later moved to the current Inkosi Albert Luthuli Central Hospital (IALCH) and remains the only TCD training facility in South Africa.

Several other independent EEG recording laboratories developed across the country as clinical interest in the modality grew during the late 1970s and early 1980s. As more private neurologists employed EEG recordists (untrained individuals) the SAMDC and later the HPCSA took over examination of EEG technicians (South Africa 1994, 2017). This made training in EEG more accessible to these recordists and helped with growing standardisation across South Africa, although until present this is not compulsory in South Africa. Other CN test modalities largely remained associated with academic centres in Cape Town, Durban, Pretoria, and Johannesburg. These procedures were included in the first scope of practice of the category CNT as illustrated in Figure 2.1 (Professional Board for Clinical Technology 1988).

EEG technicians (EE) still exist as a supportive profession to CN. These individuals have training in the performance of EEG recordings without reporting responsibilities (South Africa 1994). Qualified EE are HPCSA registered for practice under supervision of a CNP or a neurologist and play a vital role in patient care provision (South Africa 1994).

After the closure of the DoN the EEG distance course was taken over by Mr P Vermaak, initially with in-person lecture sessions and later as an online enrolment modular course. This remains the only formalised EE theory training course. It is still offered under direction of Mr P Vermaak, past president of the CNSSA and former member of the RCT and is administered through the CNSSA training web portal. This course is not a prerequisite to examination by the RCT who remains the examination convener for EE. An EEG technician review committee was convened by the RCT in 2021 to also review practical training requirements and the role of this limited scope professional in the general industry of CN.

NEUROPHYSIOLOGY

Technologists are responsible for the independent performance of electrophysiological and associated special procedures as well as tests of the brain, nervous system and muscular systems of the patient to obtain supportive evidence of these diseases. These include the following :

(a) Electroencephalography including provocative techniques, mainly in a supervisory capacity without intrusion into the role and function of the registered electroencephalographic technician in his/her capacity as a routine recordist.

(b) Polygraphy including provocative techniques.

(c) Polygraphic sleep studies including the measurement and registration of electrophysiological parameters herewith concerned.

(d) General electrophsiology

(e) Echnoencephalography

(f) Electromygraphy with the aid of surface as well as needle electrodes

(g) Electroneurogrephy with the aid of surface as well as needle electrodes

(h) Evoked Potential studies including that of the optical-, auditory- and all other somatic nerves as well as all directly related response studies

(i) Perimetry - central and peripheral fields

(j) Visual acuity tests with the aid of the Schnellen chart or similar aids

(k) Colour blindess determination with the Ishihara charts or similar aids

(l) With reference to the above, any other technique, procedure or practice directly concerned with clinical neurophysio-logical special investigations

Figure 2.1: First scope of practice of CN
Source: Professional Board for Clinical Technology (1988: 7**)**

2.3 Training and regulatory registration

2.3.1 The first technologists and development of the first National Diploma

The developments in training and course delivery brought complications regarding professional registration requirements. With the official recognition of the profession of CT the first CN-Ts were registered in 1981. According to the Government Gazette 16670 of 22 September 1995 any person who had been working in an approved unit for at least five years prior to 1 January 1980 could be registered as a CN-T (KT) with exemption to the requirement of a N Dip qualification (South Africa 1995). Prior to the Bachelor of Technology (B Tech) degree KT-S were registered as KT-S until obtaining an N Dip qualification and completing a period of 24 months of supervised experience in an accredited academic unit. A N Dip qualified CN-T could apply for independent practice registration. Upon proof of completion of the 24-month WEL period registration status would change to KT. A supervised practice technologist in this 24-month WEL period in CNT was known as a CN-T. Only after completing this 24-month period could they enter the private industry market as an independently practicing CNP and apply for a practice number from the Board of Healthcare Funders.

At the onset of recognition of professional status and registration with the SAMDC, current practitioners could apply for recognition of previous learning and experience (South Africa 1995). Qualification and course development followed shortly upon recognition of CT as a profession.

At that time these "grandfathered" KTs were required to show evidence of a minimum of five years working experience prior to 1 January 1980 (South Africa 1995). By 1995 the requirements made provision for a N Dip in CT through one of six individual technikons or a BSc Physiology, provided applicants completed two years of WIL at a SAMDC approved unit, the last four specialist category subjects (Appendix 9) of the N Dip, and a CBT (SAVKT 1986). These last four subjects of the N Dip were the category differentiation specialist subjects. 1: Anatomy and Physiology; 2: Pathophysiology; 3: Biomedical Apparatus and Methodology; and 4: Clinical Practice (Professional Board for Clinical Technology 1984). A KT specialised in neurophysiology is said to practice the profession of CN. The 1988 scope of the CNP was summarised as: "Technologists are responsible for the independent performance of electrophysiological and associated special procedures as well as test of the brain, nervous system and muscular systems of the patient to obtain supportive evidence of these diseases". This was followed by a list of 12 test modalities and investigative procedures that was considered to be within the professional scope of a qualified KT in the category neurophysiology (Professional Board for Clinical Technology 1988: 7) (Figure 2.1). These procedures were mastered during the WIL period and covered under the subject Clinical Technology Practice of the N Dip syllabus.

According to the 1991 gazetted scope of practice the category of CN summary was shortened to “The performance of electrophysiological procedures, as well as tests on the brain, nervous system and muscular systems of the patient.” and no procedures were listed (South Africa 1991: 2). This is a phrase that was originally attributed the late Mr G Hart, a founding member of the SAVKT (2020, pers. comm. 19 February, Mr H Human, member of the education committee SAVKT).

The first training model of 1978/9 comprised one year full-time on-campus introductory theoretical didactic training at a technikon, namely Johannesburg, Durban, Cape Town, and Pretoria. This was then followed by two years of WIL at an academic clinical unit. The first diplomates graduated in 1981. Figure 2.2 illustrates the course composition of the first N Dip, the so-called 1+2+2 model.

It was during this time that the SAMDC recognised CT as an official profession and registration of practitioners and formal education became a requirement. Training units were also required to be approved by the SAMDC. In 2000 the SAMDC became known as the HPCSA (Motsoaledi 2015) and a professional Board of Radiography and Clinical Technology (RCT) was established. At this time the RCT took over accreditation of training units and registration of CTs.

According to Professor J Pieterse, former HoD CT at TUT, original training units for the WIL period of the first qualifications were sourced from existing units connected to neurology training departments at academic training hospitals (2019, pers. comm 10 October). No CN needs analysis or WIL outcome evaluation was conducted and KT-S at different units were inherently subjected to differing levels of expertise and modalities as some units incorporated modalities faster than others. Available modalities and scope of exposure was determined by the needs of the associated clinical neurology department, rather than CN training needs. This difference in available CN WIL modalities has broadened with continued technological developments over the last four decades.

Diagnostic polysomnography was the next modality to be added to the umbrella of CN-T after the inception of the N Dip and compulsory registration with the SAMDC (later HPCSA) as a KT in neurophysiology.

After passing a national CBT an additional two years of supervised practice in an academic unit was required to be recognised as independently competent and to gain registration with the Professional Board of Clinical Technology of the SAMDC. In effect the educational journey towards independent practice status spanned five years – a combination of one year on-campus theory, two years WIL and an additional two years supervised practice work experiential learning (WEL). The so-called 1+2+2 model (Figure 2.2) (SAVKT 1982, 1986; Beroeps Raad Kliniese Tegnologie 1986).

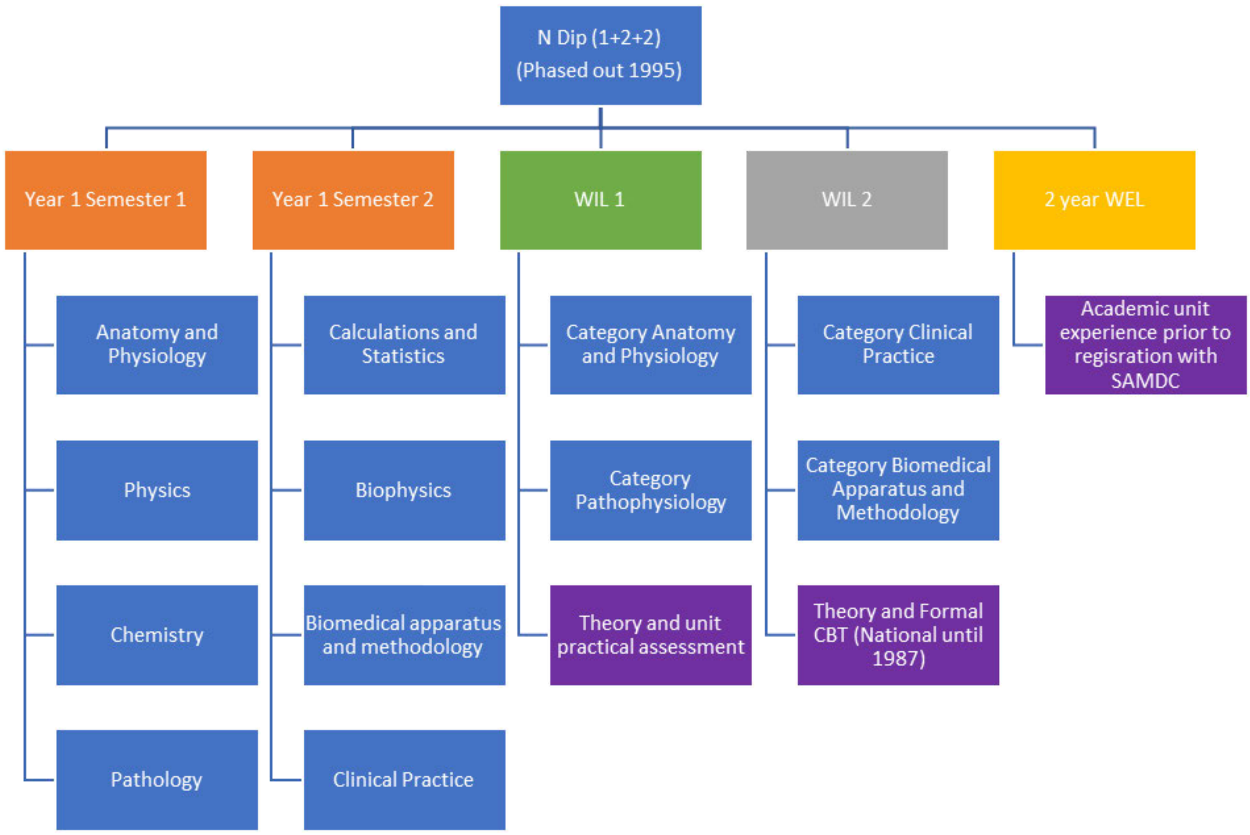


Figure 2.2: Course structure of the first National Diploma qualification

In 1984 the two-year WEL period was revised to one-year and resulted in the so-called four-year diploma and 1+2+1 model (Beroeps Raad Kliniese Tegnologie 1984). The subject offering and competency requirements remained the same.

2.3.2 Development of the second National Diploma

The second permutation of the N Dip increased the on-campus theory by replacing the first year of WIL with an additional year of full-time didactic instruction. Changes in subject offering structure and WIL period is illustrated in Figure 2.3.

Figure 2.3: Course structure of the revised National Diploma qualification

This design shortened the WIL period included in the N Dip qualification. All KTs still had to complete the national CBT and the two years of WEL were reinstated. The WIL year still included the same four category specific specialist subjects (Figure 2.3) for completion in one year instead of over two as in the previous design. All KTs still had to complete the national CBT and through the combination of WIL and WEL a three-year training period was established. The so called 2+1+2 model. (SAVKT 1982, 1986; Beroeps Raad Kliniese Tegnologie 1986; Tegnikon Oranje Vrystaat 1991; Central University of Technology [CUT] 2001; Durban University of Technology Council 2015, 2018).

Academic neurophysiology training units were not all happy with this change. Clinical technologist students' clinical training was shortened, and the CBT would be completed in each individual unit rather than on a national level. However, Professors Bartel (pers. comm 09 October 2019) and Pieterse (pers. comm. 10 October 2019) reiterated that both the learning institutions and academic clinical training units were still involved in setting of outcomes. All CN training units were also still connected to academic neurology units rather than private practices. The WEL internship also had to be completed in an academic unit for independent practice registration. Retaining the two supervised WEL years appeased most concerns as the educational journey effectively increased to five years. This 2+1+2 model thus combined two theory and three years practical experience. No formal assessment or outcomes were set for the 24-month WEL period, but clinical training unit Heads of Department (HoDs) needed to sign a letter of competency before independent practice registration could be attained (South Africa 1995). It was up to the unit's discretion whether an in-house CBT was completed before the end of the internship period.

During the transition between SAMDC and HPCSA and the inception of the RCT, two categories of registration were established: supervised practice and independent practice. The supervised practice register was used for N Dip graduates that had not completed the 24-month WEL period and the independent practice register was used to register CN-Ts that had fulfilled all academic and experiential learning requirements. In order to differentiate these different levels of practice registration in industry, independent practice, CN-Ts became known as clinical neurophysiologists (CNPs).

2.3.3 Introduction of the Bachelor of Technology degree

At the start of the 1990s CT training underwent a third metamorphosis with imagining of a four-year bachelor's degree qualification. The N Dip was a three year, 360-credit qualification, to which was added a one-year B Tech qualification leading to a cumulative 480 credit qualification. This degree consisted of the N Dip with two years on-campus learning and one-year clinical WIL followed by enrolment in the 120 credit B Tech programme. A comparison of how this course design change related to previous N Dip programmes can be seen in Figure 2.4.

According to Professors Bartel (pers. comm. 09 October 2019) and Pieterse (pers. comm. 10 October 2019) and the qualification concept documents from Technikon Orange Free State (TOFS) (now Central University of Technology [CUT]), the intention was for this B Tech study period to be completed in an RCT accredited training facility in place of the 24 months supervised practice WEL that was required of N Dip graduates prior to 2002. This model was two years on-campus with one-year WIL for obtaining N Dip, and an additional two years WEL in an academic unit while pursuing B Tech research studies.

The concept documentation made provision for the B Tech course work to be completed over one year of WEL, followed by an additional 12-month internship at the accredited academic unit. A second competency-based assessment was also implemented at some teaching units before registration with the HPCSA. Either option would then have maintained the complete training time at five years - two years of supervised practice WEL post N Dip with the added benefit of an additional academic qualification (Pers. Comm, Professors Pieterse and Bartel, October 2019; (Tegnikon Oranje Vrystaat 1991).

At the end of the 1990s and early 2000s the 12-month B Tech degree gradually replaced the 24-month post-N Dip WEL internship period as a prerequisite for independent practice registration. The last N Dip graduates that were granted independent practice registration without completing a B Tech degree were those whose training started before 31 December 1997 (South Africa 2001). Any N Dip graduate after 31 March 2001 had to complete the B Tech degree progression for independent practice registration and a new category of registration was added to differentiate between B Tech graduates and CN that completed the prior N dip plus WEL qualification. This category was then called graduate clinical technologists (KTGs) (South Africa 2007; Nhlapho 2013).

In essence the combined N Dip and B Tech course delivery structure of the B Tech qualification included a 24-month period of theoretical on-campus teaching and a 12-

month WIL period at an HPCSA approved training facility, with the optional early endpoint of an N Dip qualification. Diploma graduates could register with the RCT as "supervised practice" with no further internship or training requirements. However, a KT would have to complete B Tech studies of either one year full-time plus 12-month internship or two years part time in order to qualify for "private practice" registration.

The roll-out of the B Tech course delivery model effectively shortened the required path to qualification from five years to a possible minimum of four, as the two-year part-time model described was not compulsory. This was instituted despite the protestation of some academics and training technologists, creating further concern about graduate skills in the industry (Human 1996: 2).

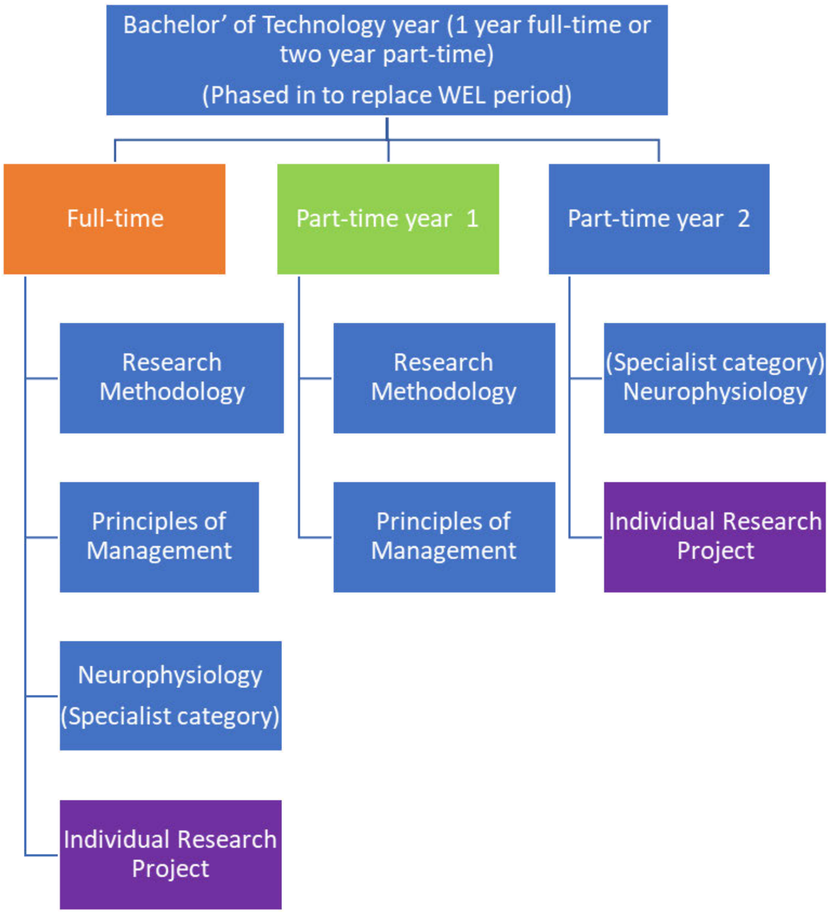


Figure 2.4: Course structure of the full-time and part-time Bachelor of Technology course

Sources for Figures 2.2, 2.3, and 2.4: Professional Board for Clinical Technology (1984CUT (2001); Durban University of Technology Council (2015); SAQA (2018); TUT (2019, 2022)

2.3.3.1 Industry complications of the B Tech qualification

Unfortunately, several changes occurred in practice, and enrolment for the B Tech degree was available to all N Dip holders without the prerequisite of working in an academic unit. Furthermore, graduates were allowed to complete the B Tech programme in one year while employed outside of an academic institution. This resulted in several practitioners with only one year of experience in an academic unit (obtained during N Dip WIL without additional 12-month WEL) and still qualifying for independent practice registration.

The bulk of accredited WIL/WEL units were historically housed in academic state hospitals. The gradual decline in paid student posts at government facilities toward the end of the 1990s, coupled with the B Tech replacing the mandatory 24-month WEL internship, led to an increasing number of N Dip qualified KTs leaving the training units after only 12 months of WIL in order to find paid employment. As they were no longer subject to supervised WEL practice in an academic unit N Dip, CN-Ts left academic units without completion of the optional B Tech year(s) and were employed as supervised practice CN-Ts.

Since B Tech qualification studies were not legally mandated to happen in an accredited training unit, despite the intention of the 1997 concept documents, supervised practice diplomate KTs were mostly enrolling for B Tech studies while working outside of an academic unit with only academic requisites for attaining the B Tech.

These B Tech enrolled KTs were in some instances supervised by an independent practice CNP, but to a larger extent by a neurologist. It was then up to the UoTs to decide how advanced assessment would be handled as these B Tech students would not necessarily be exposed to, or assessed in, a full spectrum of CNT procedures, and may not be practically assessed at all. This enrolment of B Tech students outside of training facilities became problematic as not all students had the same practical outcomes. It became a frequent topic of complaint at meetings of the CNSSA, as some universities only required written assignments and a research thesis for graduation without further practical evaluations after the third-year diplomate CBT examination.

2.3.3.2 Implications for duration of training

The length of training with the inception of the B Tech degree was shortened to a potential four years, of which only the one-year N Dip WIL would necessarily be spent in an academic unit. The B Tech model for attaining independent practice registration consisted of two years theoretical instruction, plus one-year WIL in an academic unit, followed by 1 or 2 years of theory and research study without the requirement of WEL in an academic unit. This resulted in graduates of the B Tech CT programme with independent practice registration that had potentially spent only one year of training in an academic unit.

2.3.4 The post Bachelor of Technology period

By the time of the B Tech degree inception the CNP scope of procedures had further expanded. Industry practiced modalities included diagnostic and therapeutic sleep examinations, transcranial Doppler and ultrasound investigations, and the developing field of IONM which is still mostly taught in non-academic situations.

Over the intervening years clinical demand for EPs in academic facilities decreased as radiological imaging became more accessible and few academic units could offer all procedures. Despite the dependence of IONM on competency and knowledge of multimodality EPs, most CNP units are related to clinical neurology departments whereas IONM is an adjunct of neurosurgery. With surging work demands for advanced EEG, NCS, and sleep modalities from clinical neurology, formal training and exposure to clinical evoked potentials became scarce.

To keep-up with local industry demand some units' training shifted to the original main EEG, and NCS and others offered training only in a limited scope as required from each unit's referral base (per. comm. Mrs C Bailey, Assistant director CN and clinical trainer at Groote Schuur Hospital, Cape Town. February 2020)

The lockstep of the 1980s between UoTs, training units, and industry disintegrated and the autonomy of each training unit to function without university content and outcome prescripts, as well as the enrolment of B Tech students outside of academic units or not under supervision of a CNP, led to the industry losing faith in the B Tech graduates' skills and abilities. It also led to neurologists starting to question the validity of CN independent practice status, or at least the scope of practice of CN in private practice (personal attendance, open floor discussion at the 2018 annual general meeting of the Neurological Association of South Africa).

2.3.4.1 Changes in professional registration

All CN-T in private practice up to 2001 would then necessarily be RCT registered for independent practice and no differentiation was made in the name. However, with the new B Tech degree introduced in 2000, supervised practice N Dip graduates were no longer required to stay in the academic units for 24 months and from 2002 a recently graduated N Dip qualified supervised practice CN-T could be employed in private practice by either an independent practice CNP or a neurologist. An industry differentiation was therefore necessary, and the distinction was made between supervised practice CN-T and independent practice CNPs. Clinical neurophysiologists included independent practice registered CN-Ts with N Dip qualification prior to 2002, who completed the 24-month WEL period, and B Tech graduated KTGs under the new registration regulations (South Africa 2001).

In 2013 RCT formally divided the practice registry and opened the KTG register after RCT recognised that N Dip graduates post 2002 have been incorrectly registered as 'independent practice' without obtaining the requisite WEL, or a B Tech degree (Health Professions Council of South Africa 2013). In so doing, the RCT recognised the requirement of a distinction between education qualification outcomes after replacing the 24-month WEL with the B Tech (South Africa 2007; Health Professions Council of South Africa 2013). The RCT became the only professional board of the HPCSA with this additional registration category with the intention that it would be a temporary addition since all independent practice CNPs were asked to apply for alteration of registration status and be issued with a new KTG number. Unfortunately, not all practitioners complied and according to registration statistics obtained from RCT at the end of 2021, approximately 30 CNPs were still using their KT registration numbers as independent practice category rather than private practice. To realign the RCT CT register with registers of other HPCSA boards, a decision was made to migrate all private practice registration back to independent practice (Health Professions Council of South Africa Corporate Affairs 2021).

2.3.5 The Bachelor of Health Science

The main training and education change which affected category specialisation was the restructuring to a compulsory four-year professional degree programme. The new 508-credit BHS consists of a two year on-campus programme followed by a two-year category specialisation programme combining WILL and theory instruction. This qualification was accepted and approved by both the CHE and Department of Higher Education and Training in 2014 after which each of the universities started the process of developing a four-year delivery structure and the BHS was officially registered with SAQA. In October 2016, the RCT published the inception of the qualification. The first intake of BHS first-year KT-S happened at Durban University of Technology (DUT) in the 2017 academic year.

According to the approved SAQA qualification documentation, this WIL period requires a total of 3 840 clinical instruction hours (SAQA 2018). The document specifies that this time must be completed under mentorship of a “registered practitioner” (SAQA 2018: 5). However, wording is ambiguous on whether this implies that these hours include general practical instruction during the first two on campus years or pertains to time spent in a specialist category unit. Three thousand eight-hundred and forty hours is equivalent to 480 eight-hour days, or 96 standard 40-hour work weeks.

Initially, at DUT where the BHS was piloted, these weeks would have been completed in alternating clinical and theoretical teaching and assessment blocks. Students would then spend their two-year specialisation time partly on campus and partly in their assigned clinical units. As seen in Table 2.2 this would cumulate in a total of only 71 weeks of clinical (approximately 16 months) specialised training. Training blocks could include any vacation leave units which afforded students further reduction training time.

Therefore, despite the additional 28 education credits included in the BHS, the minimum clinical training time included only four additional months from the minimum during the combined N Dip and B Tech qualification training time. The other two universities started offering BHS in the time of COVID when all lectures moved online, and students remained in their units and lectures were attended online during clinical training time.

In addition to the increased didactic hours and decreased clinical training time, the new course structure also removed the third-year, supervised practice outcome level. At

TUT the revised version retained an interim third-year-end practical assessment for progression to fourth year study, while other UoT models are reliant on unit-provided CBTs or proficiency assessments as part of a continuous assessment structure (Figure 2.5). This divergent approach to assessment furthers the uncertainty of equivalence between graduates from different UoTs.

With the DUT roll-out of the BHS the first group of graduates' fourth year of study still included an individual research project and thesis submission, however in subsequent years this was replaced with category specific group projects at two of the three UoTs (Figure 2.5 and Figure 2.6).

As the first university with BHS graduates DUT formulated final year outcome level assessment to be in the format of an OSCE, rather than the B Tech proficiency assessments. In the past these were done at each student's place of work with no objective comparative measures between student assessments at different units. The OSCE aimed at standardising unit outcomes within each university. However as can be seen in Figure 2.5, Figure 2.6, and Figure 2.7 the assessment methods within and between universities in 2023 are still not standardised.

During development of the BHS each university needed to develop course descriptor documents detailing the modular subject content for CHE registration. The researcher concentrated on module descriptors dealing with WIL delivery content and structure. Module contents from all three universities are summarised in Table 2.1

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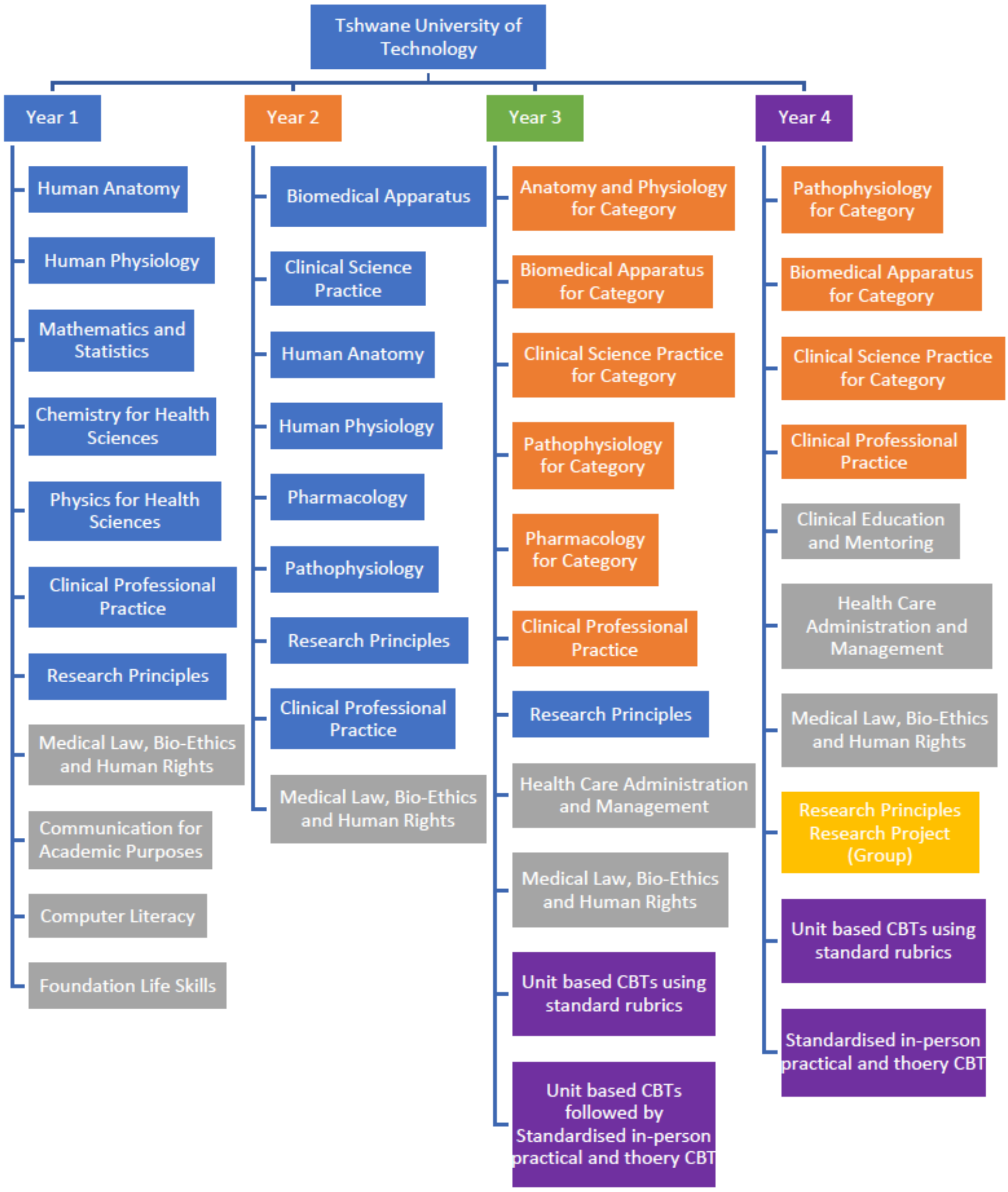


Figure 2.5: Tshwane University of Technology Bachelor of Health Science course layout

Figure 2.6: Durban University of Technology Bachelor of Health Science course layout

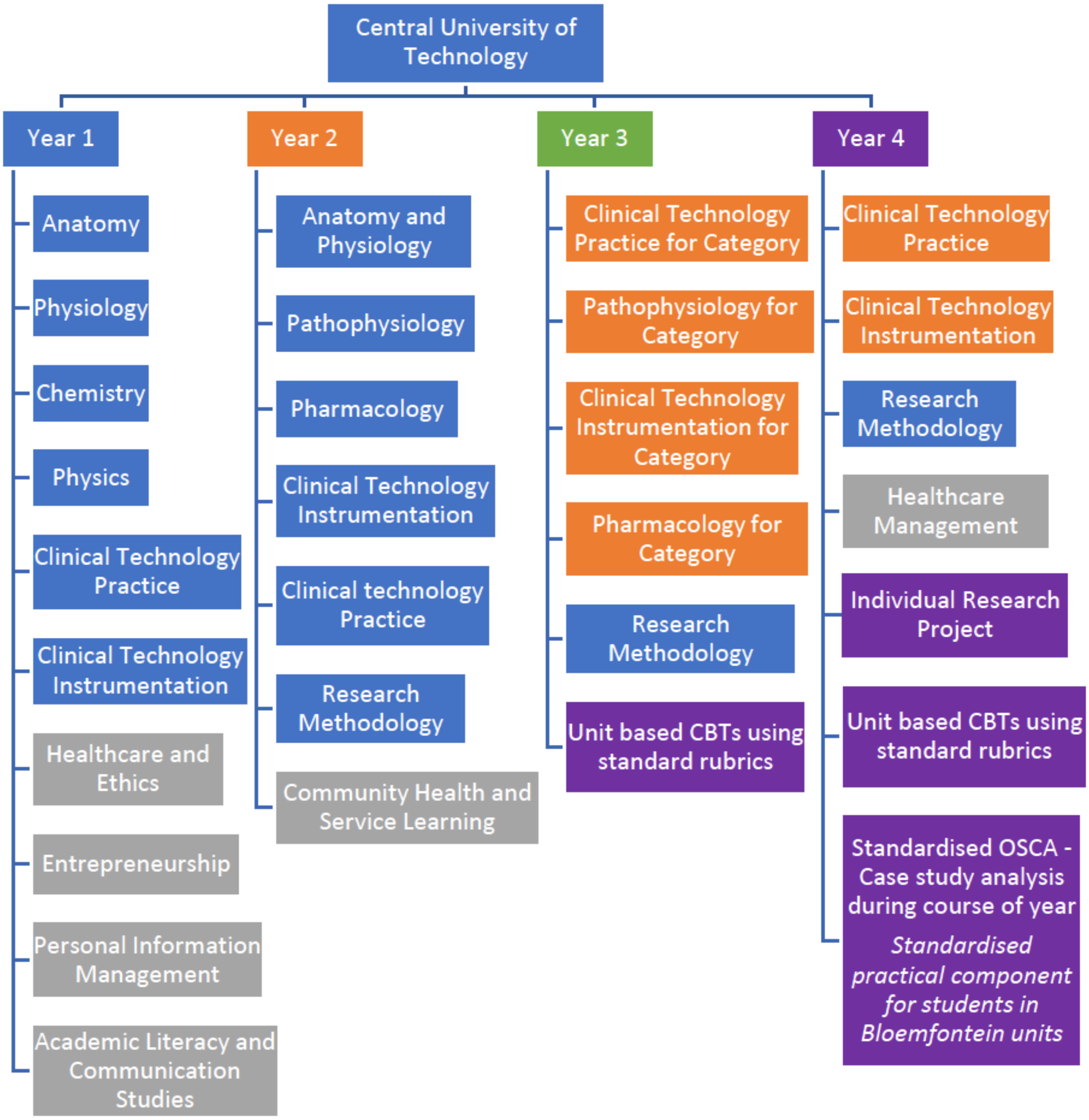


Figure 2.7: Central University of Technology Bachelor of Health Science course layout
Sources for Figure 2.5, Figure 2.6, and Figure 2.7: TUT (2022); Central University of Technology 2023; Durban University of Technology 2023)

Colour coding for Figure 2.5, Figure 2.6, and Figure 2.7: Grey: General education subjects, non-clinical technology specific; Blue: Clinical technology centred foundation subjects; Orange: Specialist category subjects; Purple: Individual graduate outcomes; Yellow: Group graduate outcomes
Abbreviations: Objective standardised assessment (OSCA), Objective standardised examination (OSCE), Competency based test (CBT)

Table 2.1: Content from BHS module descriptors

CUT:		TUT		DUT			
Third year	Fourth year	Third year	Fourth Year	Third year Semester 1	Semester 2	Fourth year Semester 1	Semester 2
EEG montages	Adult and paediatric electroencephalography (EEG)	Routine Electroencephalography	Neonatal Electroencephalography	Brain mapping	Polysomnography	Paediatric electroencephalography (EEG)	Multiple sleep latency testing
Electrode nomenclature and placement	The electroencephalogram in the unconscious patient in the intensive care	Bedside Electroencephalography	Nerve Conduction Velocity Studies LOWER LIMBS (sensory + motor)	Assist in Electromyography	Long-term epilepsy monitoring video studies	The electroencephalogram in the unconscious patient in the intensive care	Intra-operative monitoring
Normal EEG tracings	Sleep and long-term electroencephalography	Nerve Conduction Velocity Studies Upper Limbs	Brainstem Auditory Evoked Potentials	Nerve conduction studies	Memory testing and WADA testing	Sleep and long-term electroencephalography	Subdural monitoring
Abnormal EEG tracings	Multiple sleep latency testing	Brainstem Auditory Evoked Potentials	Visual Evoked Potentials (Record review - Abnormal)	Evoked potentials		Trans-cranial Doppler's	Drug administration and management of side-effects
Artefacts	Intra-operative monitoring and establishment of level of consciousness (GC scales etc).	Visual Evoked Potentials	Somatosensory Evoked Potentials				
Electro-diagnosis of neuropathies	Establishing brain death	Somatosensory Evoked Potentials	Polysomnography				
Brain mapping	Trans-cranial doppler's		MSLT (Record review)				
Assist in Electromyography	Sub-dural monitoring						
Nerve conduction studies	Drug administration and management of side-effects towards specific neurological diseases						
Evoked potentials	Intramuscular nerve conduction						

CUT: Third year	Fourth year	TUT Third year	Fourth Year	DUT Third year Semester 1	Semester 2	Fourth year Semester 1	Semester 2
Polysomnography	Evoke potentials						
Long-term epilepsy monitoring video studies.							
Memory testing and WADA testing							
Multiple sleep latency							

Sources for Table 2.1: Tshwane University of Technology 2022; CUT 2023; Durban University of Technology 2013c, 2013d, 2013a, 2013b, 2023; Central University of Technology 2014, 2015; Tshwane University of Technology 2018a, 2018b

2.3.5.1 Impact of COVID-19

The COVID-19 pandemic and associated lockdowns and social distancing severely impacted this block structure. First and second group BHS KT-S were impacted when their clinical time was interrupted by mandatory stay-at-home. Upon their return to units a shift was made to online lectures with some universities choosing to host lectures during workhours, and others mainly after traditional work hours. This is still in place in 2023. The extent of clinical training interruption is therefore uncertain. However, it is clear that the full 3 840 clinical instruction hours are not dedicated to category specific clinical specialisation and little real increase in WIL time has been achieved.

A fourth-year standardised analysis (case study) assessment at the end of the study period replaced the previous third-year CBT at two of the universities. Unfortunately, due to the Covid-19 (COVID-19) pandemic restrictions; these assessments needed to be done virtually and no standardised practical assessments could be done. Therefore, some graduates were only ever practically assessed inside their training units with no outside standardisation or quality control. Referring to Figure 2.5, Figure 2.6, and Figure 2.7, it is clear that the practical competencies and theoretical proficiencies are assessed differently at all three universities.

Table 2.2: Block rotation for 2019 BHS at DUT

	January	February	March	April	May	June	July	August	September	October	November	December
3rd year	Block training	Block training	Block lecture	Block training	Block training	2 weeks at DUT for tests + 2-weeks block training	Block training	Block lecture	Block training	2-week Block training + 2 test week at DUT	Block training	1 week block training + 3 weeks vacation
									33 weeks of block training + 12 weeks of Block lecture			
4th year	2 weeks off + 2 weeks Block lecture	Block training	Block training	Block training	1 week – tests + 3 weeks Block training	Block training	2 weeks Block training + 2 weeks block lecture	Block training	Block training	2 weeks – tests + 2 - week block training	Block training	3-week block training + 1 week vacation
									38 weeks of block training + 7 weeks of block lecture			

Source: Department of Biomedical and Clinical technology (2018)

Table 2.3 is a summary and comparison of the developments in both education and registration requirement developments.

Table 2.3: Development of CNT training and registration in South Africa

	CT and CN Training	Recognition and regulation of profession
1970s	1970s EEG technician certification – NIPR CSSR:	
	3 Months didactic instruction and 12 months WIL (Bartel 2019, pers. comm. 09 October)	
1976-1978	Formulation of first CT N Dip consisting of 1-year didactic study followed by 2 years WIL training and two years WEL (1+2+2), (2019, pers. comm 10 October)	**1975 Formation of CT Society and definition of 5 categories including CN (Human 1996)**
		1981 Recognition by SAMDC of CT as profession (Human 1996).
		1982 Establishment of first professional board for CT (South Africa 1982) with educational requirements for registration as KT
		Pathway One: Grandfather clause for practitioners with more than 5 years practical training experience (CN).
		Pathway Two: N Dip 1+2+2-year WEL at academic training unit.
1984	First revision of three-year N Dip (SAMDC 1986).	**1984 Revised N Dip 1+2+1-year WEL at academic training unit**
	One-year didactic instruction and 2 years WIL, followed by 1-year WEL in academic training unit. (1+2+1) (Beroeps Raad Kliniese Tegnologie 1986)	Required training time reduced by 12 months.
	1986 Addition of Critical Care and Reproductive Technology to national curriculum	
1994	Revision of N Dip to 2 years didactic study followed by 1-year WIL training and 2 years supervised training in accredited unit. So-called 2+1+2 (South Africa 1991, 1995)	Required training time increased by 12 months in preparation for replacement with B Tech.
	Proposal to develop B Tech degree to replace supervised practice WEL period. So called 2+1+ B Tech (South Africa 1995).	
1996	Enrolment of first revised N Dip students.	1998 Professional Board for Radiography and Clinical Technology established in terms of section 15(1) of the Act, as published under Government Notice No. R. 75 of 16 January 1998. **Establishment of KT supervised practice and independent practice registration categories.**
1997	Roll-out of new 3-year N Dip. Two-years didactic instruction and one-year WIL (2+1+ optional WEL or B Tech)	**N Dip qualified KT for supervised practice registration, apply for WEL recognition to update registration to independent practice category.**
	Formalisation of BTech (cumulative 480 credit qualification with inclusion/recognition of N Dip credits)	Last registration of independent practice obtained after 24-month WEL in academic unit (no B Tech graduates yet)
1998	First roll-out of BTech independently of N Dip.	**First registrations of graduates registered as Supervised practice after obtaining N Dip without WEL option to progress to independent practice.**

	CT and CN Training	Recognition and regulation of profession
	First enrolment of 2+1+ B Tech students	Professional Board for Radiography and Clinical Technology established in terms of section 15(1) of the Act, as published under Government Notice No. R. 75 of 16 January 1998
	Single pathway option: 2+1+ B Tech with industry expectation of two-year part-time study in academic unit, however no Gazetted requirement for B Tech to be completed in academic unit (South Africa 2001).	
	N Dip three-year diploma qualification as first qualification followed by B Tech as additional qualification (South Africa 1991). No mandatory academic unit WEL internship period.	CBT at end of training became a recommendation with UoT determination of clinical evaluation. The outcome practice registration category level of N Dip and B Tech was defined (Board for Radiography and Clinical Technology 2002)
	12 Months internship in accredited unit, no longer only academic unit (Bartel, Verster, Pieterse 2019, pers. comm 10 October 2019) OR Achievement of 120 credit B Tech degree.	**B Tech start to replace 12-month WEL as prerequisite for independent practice registration for N Dip graduates started after 31 Dec 1997** **Second registration as independent practice.**
2001	First graduation of 2+1 N Dip + B Tech without requirement for 24 months supervised practice between RCT category registration change	**2001: Last HPCSA recognition of 2+1+2 graduates for independent practice**
2007	Retrospective review of training requirements for registration. Training prior to 1997: minimum three years clinical experience in an academic unit (1+2+2) Training post 1997: minimum one-year clinical training in an academic unit (2+1+2)	**2007 HPCSA registration category for KTGs are promulgated to differentiate between KT graduated before and after B Tech roll-out (Department of Health 2007) – to be implemented retrospectively).** **(Training prior to 1997 required a competency-based test conducted by the council) (Training post 1997 competency-based test was unit specific (Board for Radiography and Clinical Technology 2002) (Department of Health 2001)**
2016	Development of 4-year BHS degree (2+2) with industry proposed 2-year period of supervised practice/internship	
2019	Enrolment of first BHS students and last enrolment of B Tech.	**2020 HPCSA RCT resolves to uphold a 2-year work experience period for BHS graduates as prerequisite to opening and conducting a private practice**
2020		**2020 HPCSA RCT resolves to uphold a 2-year work experience period for BHS graduates as prerequisite to opening and conducting a private practice**
2021	Graduation of first BHS graduates	2021 HPCSA revokes 2-year supervised practice internship.
	Single pathway option: BHS degree 4-year degree (2+2).)	**Registration category limited to HPCSA registration independent practice KTG.**

2.4 Present training facilities

Presently individual neurophysiology clinical training units are nominated for accreditation to training status by the UoTs and follow the prescripts of the individual UoTs' suggested WIL training structures (Board for Radiography and Clinical

Technology 2009: 1). These structures do not make provision for category specific delivery needs and therefore do not include content guidelines. This lack of guidelines to clinical units leads to non-standardisation of the modalities and outcome skill levels (OSL) taught by individual WIL providers within one UoT. WIL training units accredited to multiple UoTs therefore have the added challenge of navigating potentially vastly differing course structures and may contend with differing training outcome goals.

Units are either approached by universities to act as training facilities or can offer their availability to universities. Each unit and university then submit accreditation applications to RCT for consideration of accreditation. At present there are only nine accredited units with a combined maximum KT-S capacity of 25 (pers. comm. email 10 August 2023 Ms Veli Lukhozi, Deputy Company secretary: Dental Therapy & Oral Hygiene, Medical Technology, Radiography and Clinical Technology). These are summarised in Table 2.4. With the inception of the BHS the yearly third-year intake halved from the N Dip intake as students would now remain registered with RCT as a KT-S for two years instead of one. This would equate to a yearly maximum intake of approximately 12 new CNT KT-S per year across all three OuTs if all units except the maximum number of students, however from personal experience this is rarely the case.

Table 2.4: Clinical neurophysiology training units May 2023

CUT	DUT	TUT	Training Centre	Province	Student Allowance
X			Bernice Terblanche	Free State	1
X			Groote Schuur Hospital	Western Cape	2
		X	Steve Biko Academic Hospital	Gauteng	4
X	X	X	Inkosi Albert Luthuli Central Hospital	KwaZulu Natal	4
X			Universitas Academic Hospital	Free State	4
		X	Liechka Groenewald Inc	Gauteng	2
	X		Greys Hospital	KwaZulu Natal	4
X			Bloemfontein Sleep Laboratory	Free State	2
		X	Peet Vermaak	Mpumalanga	2
Total					25

Source: Ms Veli Lukhozi, Deputy Company Secretary: Dental Therapy & Oral Hygiene, Medical Technology, Radiography and Clinical Technology

2.5 Modalities included in training

Table 2.5 summarises the list of training procedures compiled from training documents and personal experience as current in 2023. These categories were identified according to historic teaching, learning, and assessment (TLA) documents spanning the period from 1984 up to the development of the BHS module descriptor documents.

Modalities were deemed to be related considering the equipment used, the pathology investigated, and the nervous system structures tested (Durban University of Technology 2017; Tegnikon Oranje Vrystaat 1991; Durban University of Technology 2013a; Central University of Technology 2014, 2015; Tshwane University of Technology 2018c; pers. comm. with current WIL educators for TUT, DUT, and CUT. Mrs J Verster, Mr Peet Vermaak, Mrs A van der Merwe, and Dr J Janse van Nieuwenhuizen are educators for TUT and together with Mrs J Le Roux, from CUT, were all interviewed during the 2019 CNSSA Annual congress, Mrs C Baily was interviewed at Groote Schuur Hospital on 10 February 2020 where she is WIL unit manager accredited for CUT and DUT). The author served as part-time lecturer for DUT between 2016 and 2020 and continues to serve as WIL instructor for both DUT and TUT.

Table 2.5: Condensed list of CNT modalities from N Dip, B Tech and BHS training documents

	Modalities
Group 1	Neuromuscular
1	Needle Electromyography (Assist with Electromyography)
2	Nerve Conduction Studies
Group 2	Evoked Potentials
3	Auditory Evoked Potentials
4	Flash Visual Evoked Potentials
5	Pattern Reversal Visual Evoked Potentials
6	Somatosensory Evoked Potentials
Group 3	Electroencephalography
7	Bedside Electroencephalography
8	Neonatal Electroencephalography
9	Routine Electroencephalography
Group 4	Long-term monitoring
10	Continuous ICU Electroencephalography
11	Long-term EEG video monitoring using grid recordings
12	Long-term EEG video monitoring using surface electrodes
Group 5	Intraoperative

	Modalities
13	Intraoperative neuro-monitoring using multi-modality evoked potentials
14	Cortical brain mapping
15	Deep brain stimulation
Group 6	Sleep
16	Polysomnography
17	Multiple sleep latency test
18	Maintenance of wakefulness test
Group 7	Sonography
19	Transcranial Doppler
20	Peripheral nerve and muscle ultrasound
Group 8	Other
21	Drug administration and management of side effects
22	Memory testing
23	WADA testing

2.6 WIL methods in healthcare education

It is important to realise that cooperative education as a model for learning has existed in South Africa since 1979 (Reinhard *et al.* 2016). Therefore, the idea of utilising WIL to promote the TLA experience for students is not new to the South African education environment. Work integrated learning and WEL are well known terms in the South African teaching environment as a strategy of applied learning (learning integrated with work) and is often viewed as an umbrella term to capture the various elements of practical-based education. In essence, WIL is a cooperative education between institutions and places of work characterised by a planned series of practical experiences. These experiences are aimed at guiding the student to gradually assume personal and professional responsibility.

Engel-Hills *et al.* (2010) postulated that the term 'work-integrated learning' is descriptive of an approach to career focused education that includes appropriate theoretical forms of learning to the relevant field of study in conjunction with a combination of problem-based learning, project-based learning and WBL with the distinguishing factor being the emphasis of WIL on integrating theory instruction with practical application.

Another form of WIL is experiential learning. Work experiential learning (WEL) is defined as a cycle of learning and described by Kolb (1984) involving action, reflection, experience, and abstraction. Combined this promotes the cultivation of interest and effort into active learning (Marsh-Nation 2019: 24).

Groenewald (2004) defined WIL as an educational strategy whereby students combine academic learning at a university with time spent in a workplace relevant to their programme of study and career aims. According to Groenewald (2004), four key elements form part of any successful WIL based learning programme: an integrated curriculum; a WBL experiential component; several workplace training units offering student placement and input regarding updates to the curriculum; and a well-defined programme guideline on the organising, coordinating, and assessment of students. Coll and Zegwaard (2006) found that despite the widespread use of WIL only a few reports on the methods and practice of teaching are available. They also raised the point of graduate competencies, so-called “soft skills”, and graduate profiles that may differ between stakeholders. They argued that understanding of stakeholder views forms an essential prerequisite for pedagogical design of efficient WIL programmes.

Fundamental to successful WIL is a three-way partnership between the student, workplace, and university. This partnership requires that all parties accept definite responsibilities, perform specific functions, and achieve benefits resulting from the involvement (du Plessis 2019).

Despite strong policy directives to include WIL in tertiary education (Council on Higher Education 2011), little previous South African research on WIL programmes have been conducted at higher education institutions (HEIs) despite the role that higher education plays in workforce development (Winberg 2006). Cooper (2010) wrote that there has been scarce discussion of the theory of WBL in South Africa, and practically no evaluative research to trace the impact of WIL programmes in science and technology fields of study at technikons (now UoTs). There are thus few examples of major research projects in WIL TLA (Winberg 2006). More recently, though, a few evaluations have considered WIL provider and student perceptions on student preparedness for entering WIL at UoTs (Ngwane 2016; Prakaschandra, Meyer and Bhagwan 2023). These will be discussed in the student benefit of WIL section.

Considering the scarce research into CT education and only two international investigations of CN WIL, it was necessary to look at research into WIL models used by other allied health and paramedical sciences educators, but also to look at the various modes of experiential learning included under the umbrella of WIL.

The review of any WIL structure is imperative if it is to promote higher education institutions and industry partnerships, as well as to positively influence the employability of higher education graduates. Consultations with stakeholders for approval, support and review and successful WIL depends on the meaningful interaction between all stakeholders along the TLA pathway (Govender and Taylor 2015; du Plessis 2019). Batholmeus and Pop (2021) concluded that "it is necessary to consider … alignment of curriculum with labour market demands when considering the integration of industry-based WIL" (Batholmeus and Pop 2021: 157).

Govender and Wait (2017) investigated the benefits of WIL for student career prospects. Their premise was that HEIs are expected to provide students with a strong knowledge base and the ability to apply this knowledge at work.

Employers demand that HEIs provide a strong knowledge base to their graduates and are especially concerned if these graduates are not equipped to apply that knowledge at work (Govender and Wait 2017). The benefit of any form of WIL includes pushing students to be productive and to do real work that translates into social and economic values. One of the fundamental challenges is the demand for relevant skills for the labour market (Batholmeus and Pop 2021).

In order to develop a standardised education model, the concept and limitations of a WIL programme must be understood. For any WIL programme to succeed in its purpose – i.e., category specialisation in CN – the programme must be set-up in such a way as to facilitate adequate learning and meaningful experience in the relevant field of study (Gibson *et al.* 2002).

In most WIL projects the workplace educator controls all interaction between the organisation and the students, including student placements, site visits, ongoing monitoring of student work and progress, and assessment of student learning and performance that occurs during their placement period (Holdsworth, Watty and Davies 2009; Govender and Wait 2017).

Du Plessis (2015; 2019) found that WBL in radiography, although a major component of WIL in its currently understood form, is not the only environment in which learning can take place for integration between theory and practical implementation. A standardised WIL curriculum will assist students to shift between the application of practical skills and competencies, and the theoretical knowledge provided by the UoT course content (du Plessis 2019). It is therefore important to first investigate and define the contents of a well-developed WIL programme.

To enhance the quality of learning and teaching, lecturers must attempt to match and modify their teaching strategies to allow for students with different needs. It is necessary for all educators to structure their classes or teaching to accommodate a wide range of students with different expectations (Mohapi 2017).

Predetermined outcomes and organised learning outcome assessment criteria help to improve student outcomes through assisting students to use feedback to improve their own performance and reflection on learning (Jaekel *et al.* 2011). It was thus the aim of this study to investigate and determine the required outcomes for WIL in CN.

Engel-Hills *et al.* (2010) went further to present a structure of four types of practical learning used in South African WIL with defined relationships and with differing levels of study and qualifications (Table 2.6). In their structure bachelor studies were matched with short workplace learning placements.

Table 2.6: Work integrated learning in different qualifications levels

Qualification	Work-directed theoretical learning	Problem based learning (PBL)	Project based learning (PjBL)	Workplace learning (WBL)
Certificate	Yes	Yes, Short and Focused	No, Insufficient time	No, Insufficient time
Diploma	Yes	Yes, Short and Focused	Yes, Short and Focused	Yes, short placement
Bachelor	Yes	Yes	Yes	Yes, short placement
Master	Yes	Yes	Yes	Yes, combined with PjBL
Doctor	Yes	Yes	Yes	Yes, combined with PjBL

Source: Engel-Hills *et al.* (2010)

2.6.1 Work integrated learning in allied health professions

The aim of a WIL programme is to integrate practical and theoretical training in a model of cooperative education between HEIs and their training partners. Since its development WIL has remained fundamental to a spectrum of health care professions. To increase employability of health professions graduates, WIL must be planned in consultation with stakeholders for review, approval, and support (Govender and Taylor 2015: 48; Ngwane 2016; du Plessis 2019). Development of the first WIL programmes coincided perfectly with the development of the first model of CT training and WIL remains at the heart of all three of the current UoT programmes.

The continued success of WIL needs recognition and clear agreement between all stakeholders including employers, students, and HEIs with attainment of mutual benefit (Ngwane 2016; du Plessis 2019). The aim of WIL is, after all, for students to gain requisite knowledge, skills and attitudes suited to their future profession. This must however be accomplished in meaningful interaction between all stakeholders where all parties accept well defined responsibilities and achieve mutual benefits from performing specific functions during this collaborative and interactive teaching process (du Plessis 2019). Additionally, Engel-Hills *et al.* (2010) state that qualification appropriate learning should be demonstrated and should be assessed regardless of whether it takes place in the clinical training unit or is provided in the institution of learning. Either way, assessment of the appropriateness of learning to a specific industry or profession requires understanding of industry needs or requirements.

2.6.2 Student benefit of work integrated learning

Schuster and Glavas (2017) concluded that the ever-increasing focus on WIL is driven by the need for work-ready graduates. Therefore, development of WIL is a strategic priority for universities that aim to improve employability of graduates (Schuster and Glavas 2017).

Students are expected to derive several benefits from WIL experiences, including development of relevant discipline specific skills, personal attributes, and the ability to communicate effectively in the work environment (Govender and Wait 2017).

Work integrated learning plays a fundamental role in the training of healthcare professionals across a spectrum of disciplines. The main intention of WIL is for students to acquire this relevant knowledge, skills, and attitudes necessary for their future professional work.

Work integrated learning forms the basis of specialisation in all seven CT categories. Employers increasingly demand that graduates should be provided with a strong knowledge base and the ability to apply that knowledge upon graduation (du Plessis 2019). Work integrated learning serves to increase students' awareness of the relationship between work and learning and forces students to become productive (Govender and Wait 2017). Work integrated learning is also considered to enhance employability through development of personal attributes such as teamwork, self-management, and critical thinking skills that are integral to entering the "world-of-work" as described by Ngwane (2016) in his study of DUT student perceptions of WIL. Govender and Wait (2017) proposed that authentically assessed learning through WIL builds student character and creates graduates fit for future employment (Govender and Wait 2017). Work integrated learning offers students opportunity to gain confidence to apply theoretical knowledge in various methods during placement in a practical setting and therefore find how this knowledge can best be utilised in a real-world setting (Reinhard *et al.* 2016). Thus, students benefit from WIL in more ways than just increased job knowledge. Work integration also facilitates personal development and improved attitudes toward work readiness (Govender and Wait 2017). Ngwane (2016) found that students perceive a benefit in comprehending the relationship between theory and practice. Through this comprehension their studies then become more meaningful. Additional to gaining confidence students also develop interpersonal communication and problem-solving skills during WIL (Ngwane 2016). These findings were confirmed by Prakaschandra, Meyer and Bhagwan (2023) who recorded student comments regarding adaptability, accountability, and teamwork. Students also found benefit and motivation in being surrounded by knowledgeable and confident professionals.

From an academic institution perspective, the success of WIL is dependent on the institution understanding industry requirements through continuous engagement between the university and industry (Ndlovu 2019). The reverse is also true and Prakaschandra, Meyer and Bhagwan (2023) reported how DUT students in CT perceived their own levels of theoretical preparedness to be different to fellow CT students from other HEIs. This difference in preparedness places a strain on WIL providers to develop the same skills in students from different HEIs, underscoring the importance of UoTs receiving industry input that they can then provide to WIL units for more comparable outcomes for all UoT CN WIL training.

2.6.3 Work-integrated learning in South African clinical neurophysiology technology training

It is necessary to first determine desired graduate course outcomes before comments can be made on the validity or appropriateness of current CNT training. Only after confirming the required outcomes and how these outcomes possibly relate to each other will it be possible to evaluate and design a structured framework for WIL delivery in which these outcomes can be achieved (du Plessis 2019).

No previous investigation into workplace needs or required student outcomes in South African CNT training has been done. It is unknown whether the investigation into student WIL preparedness by Prakaschandra, Meyer and Bhagwan (2023) included CN students. None of the three UoTs that offer CT have guidelines regarding what WIL means, or how this time should be structured within the clinical training units. The work by Prakaschandra, Meyer and Bhagwan (2023), however, does show that preparedness differs between UoTs and can be extrapolated to include differences in WIL outcome requirements. Further, no training in WIL teaching is offered to clinical training unit personnel entrusted with the specialist education of KT-S. Du Plessis (2019), found this oversight mirrored in the education of radiographers in South Africa and proposed that a credit-bearing structured course should be offered. Batholmeus and Pop (2021) also found a lack of WIL educator training in teacher learning at technical vocational education training colleges in South Africa.

2.7 The importance of experiential learning for work-integrated learning

The importance of using learning modes such as problem-based or scenario-based learning or project-based learning (PjBL) in the WIL environment to promote the integration of theoretical knowledge and workplace skills, is clear. Shalem and Allais (2018) explored the relationship between experience and learning through work. They proposed three key questions to answer: “What does one need to know in order to be an expert in what one does?”; “How does one grow personally as a result of subject expertise within the occupational context?”; and “How does being a member of an occupation contribute to one’s being a citizen?” (Shalem and Allais 2018: 6-7). Each mode of WIL brings slightly, but significantly, different skills to the fore. The importance of experience through work, and the benefits and differences between the different modes, must be emphasised and addressed when the WIL component of learning programmes is developed to ensure the WIL component is optimally effective for the field of study (Kolb and Kolb 2009; du Plessis 2019). It is therefore important to state exactly what needs to be included in the WIL period to adequately answer the three questions posed by Shalem and Allais.

Before embarking on an in-depth investigation regarding appropriate WIL delivery methods for WIL in CN it must be investigated what the requirements for WIL are. However, investigation into the major modes of WIL delivery is outside the scope of this manuscript. The focus of the current study is on industry integration outcome requirements and how these outcome skills build upon each other, rather than who delivers the WIL training.

2.8 International articulation of South African qualifications

The previous iterations of CT training in South Africa mentioned international professional articulation options for the different categories. However, no mention was made of international training articulation requirements (SAQA 2006, 2012; 2018; Central University of Technology 2017).

Several of our pre-2001 N Dip and later B Tech CNT graduates are successfully employed as CNPs in various international institutions. The author personally spent a prolonged period employed internationally and knows from personal experience that our training has been positively accepted internationally.

2.8.1 International clinical technology and clinical neurophysiology technology education and registration requirements

Literature review found only three previous investigations of CT education. Wider search for education in any of the CNT modalities as listed in Table 2.5 found only one additional investigation of EEG educational methods focusing on training doctors (Kander and Wilmshurst 2015).

A single journal article was found investigating the efficacy of current educational programmes in perfusion technology in South Africa (Ali-Musa *et al.* 2018). The investigation found agreement in perfusion educator perception that no inter-university or unit standard practices exist. Additionally, educators agreed that curriculum revision is needed, and a national independent exit exam would benefit patient care (Ali-Musa *et al.* 2018: 34).

Two non-published educational dissertations were found that focused on the educational and assessment methods in CT.

The aim of the first study was standardisation of evaluation to ensure an adequate level of understanding at the end of the N Dip education programme (Human 1996). This was conducted during the inception of the B Tech programme. Human (1996) found that recent graduates were uncertain about the aims of knowledge and practical skill evaluations. He also reported that recently qualified CTs did not understand how their practical year marks were determined. At the end of his study, he introduced Bloom's taxonomy as a method of standardisation in assessments. He found only 3% of mark allocation during final year assessment papers were for higher order cognitive skills (Human 1996: 119) and that practical assessment were inherently subjective to the evaluator. Looking at his work it is apparent that little has changed in the methods of practical assessment currently used, despite his advice for practice directed restructuring and detailed description of training outcome goals. He also advised that these descriptions should include cognitive (knowledge, understanding), psychometric (analysis, interpretation, creation), and affective (interest, attitude, enthusiasm, moral responsibility) domains of the taxonomy (Human 1996: 120-122).

The second dissertation was more recent. It focused on modification of assessment methods of CT students in general education. Dr J Mohapi from the DUT investigated the use of an integrated teaching and learning model using assessment as a tool to increase student understanding of learning. Integrating assessment into teaching was found to increase efficiency in teaching and quality of learning (Mohapi 2017), improving second year student perception of learning, knowledge, and understanding (Mohapi 2017: 171). The investigation confirmed Human's (1996) observation that examination papers omitted the domains of application, evaluation, and creation (Mohapi 2017: 181).

Despite valuable insights into TLA of CTs, both these dissertations looked at outcomes' evaluation, teaching methods and assessments without distinguishing between CT categories at either the general education or specialisation level.

2.8.1.1 International models of CNT training

The most well-known international articulations of CNT training are from the American Board of Registered Electroneurodiagnostic Technologists (ABRET) which involves exams in individual CNT modalities (Gustafson 2023). However, sleep modalities and NCS are credentialed by separate boards with independent qualification criteria (The American Association of Electrodiagnostic Technologists [AAET] 2023; Board of Registered Polysomnographic Technologists [BRPT] 2023).

The Canadian model is comparative to the USA where the majority of teaching and learning is in-service training based, with career orientated two-year associate degrees available, but not compulsory (Dash *et al.* 2017).

Similarly, Australia does not require formal education or examination, but rather focuses on the job training (OtJT) and WEL, although employers may have individual requirements (The Association of Neurophysiology Scientists of Australia Inc [ANTA] 2020).

In the United Kingdom CN is one of the medical scientist professions requiring employment and training through the National Health Services (NHS) (National Health Services 2023a).

2.8.1.1.1 United States of America

The Neurodiagnostic Society, also known as ASET – The Neurodiagnostic Society and previously known as the American Society of Electroneurodiagnostic Technologists (ASET), developed educational standards and educational accreditation standards for neurodiagnostic technology (NDT) in 1973 with subsequent revisions (American Academy of Neurology, *et al.* 2017a). Additionally, they published add-on guidelines for each modality category which are continuously updated as technological advances are made (American Academy of Neurology *et al.* 2017a, 2017b, 2020c, 2020d, 2020e, 2022a, 2022b, 2022c, 2022d).

The American neurodiagnostic credentialing and accreditation body is known as ABRET Neurodiagnostic Credentialing and Accreditation using the acronym of their original name: The American Board of Registered Electroneurodiagnostic Technologists (ABRET). The organisation is responsible for the majority of NDT credentialing examinations. They currently offer seven qualifications (ABRET 2022a, 2022b, 2022c, 2022d, 2022e, 2022f).

The BRPT is the credentialing organisation for sleep modalities and offers three credentials: certified technicians, registered technologists, and a certification in clinical sleep health for non-technologist patient educators (BRPT 2023). The American Association of Electrodiagnostic Technologists (AAET) (also known as The Nerve Conduction Association) is the examination and credentialing organisation for NCS in the USA (AAET 2023; The Nerve Conduction Association [AAET] 2023). All three organisations publish new candidate handbooks on their websites yearly

All three organisations offer students multiple educational pathways to qualify for examination. A common thread is the requirement for WIL experience and completion of an NDT training programme accredited by the Commission on Accreditation of Allied Health Education Programme. This includes programmes offered by ASET related academic health centres with OtJT. This can be compared to the current CNSSA EEG technician course with HPCSA requirement for supervised practice experience (CNSSA 2019).

Community college two-year electroneurodiagnostic associate degrees are also available as detailed in each examination candidate handbook. These correspond well to the first two years of on-campus academic training of the N Dip and now BHS. However, only the University of North Carolina offers a bachelor’s degree in Neurodiagnostic and Sleep Science (UNC School of Medicine 2020).

Specialist category learning is mostly done by enrolling in private learning courses, as part of in-service training, or as self-study. This is however slowly changing and the latest ABRET candidates’ handbooks strongly lean towards the requirement for more formalised teaching. Clinical neurophysiology technology careers in the USA are not regulated or licenced, meaning a practitioner is not mandated to be Board credentialed and therefore no minimum tertiary qualification is legally required to practice in the field.

2.8.1.1.1.1 USA Involvement in training in Africa

In more recent years ASET in collaboration with Global Organization of Health Education has offered EEG training in Africa and Asia. Together with the International League Against Epilepsy they have facilitated the formation of the African Neurodiagnostic Society and developed a neuroscience training programme at Mekelle University in Ethiopia (International League Against Epilepsy. 2023). This programme is also supported by ABRET (Global Organization of Health Education 2023) with the aim of learners completing the ABRET EEG technologist examination.

2.8.1.1.2 Canada

The Canadian education and credentialling pathways for EEG technologists through The Canadian Board of Registration of Electroencephalograph Technologists compare well to the ABRET requirements and the USA and Canada recognise each other's credentials.

The Association of Electromyography Technologists of Canada recognises the Board of Registration for Electromyography Technologists of Canada examination (Association of Electromyography Technologists of Canada 2023). According to the Canadian Government Job Bank employers may require education and credentialing, but only the territory of Alberta regulate education requirements for Electroneurophysiology Technologists and EEG Technologists (Government of Canada 2023).

Credentialing and formal training therefore remain mostly optional for employment in Canada. Patient care and training therefore may consist of only OtJT in the place of employment (Gustafson 2023).

2.8.1.1.3 Australia

Two bachelor education qualifications are available in Australia with a third university offering post graduate education in CN.

The Association of Neurophysiology Scientists of Australia (ANSA), previously known as the Association of Neurophysiological Technologists of Australia (ANTA), is the representative association for the profession. In 2018 ANSA published a suggested training pathway document (Association of Neurophysiological Technologists of Australia Inc 2018). This one-page document offered two entry points to the profession. The first was completion of a bachelor's program and the second was employment-based with enrolment in an ANSA recognised theory offering. The endpoint would then be completion of an ANSA competency in at least EEG followed by further competencies in additional CNT testing modalities.

Similar to ASET in the USA, and CNSSA in South Africa, ANSA aims at promoting education and training (ANTA 2023). Unlike ASET and CNSSA that offer only training opportunities, ANSA also offers competency evaluations in EEG, EP, IOM, and NCS (Association of Neurophysiological Technologists of Australia Inc 2019).

2.8.1.1.4 United Kingdom

Clinical neurophysiology is practiced in the United Kingdom (UK) by NHS health science practitioners, NHS health scientists, and NHS clinical scientists with specialisation in neurophysiology (National Health Services 2023b). These professions fall under the umbrella of physiological scientists. The levels of classifications have similarities in scope and supervision to the HPCSA RCT EEG technician, KT supervised practice and KTG independent/private practice categories. There are however several other intermediate practice levels within the field with requirements ranging from WEL apprenticeship to advanced science degrees and practice years.

Clinical training is provided by the NHS. Admittance to training programmes of different levels have specific educational requirements. Teaching, learning and assessments are performed in both theoretical assessment and clinical assessment in NHS training facilities for the in-service apprenticeship levels.

Basic entry level qualification to enter an NHS practitioner training programme in neuroscience is a high school A-level education with science subjects. Training consists primarily of WEL and assessment.

Application for the NHS clinical scientist training programme requires a healthcare science undergraduate honours degree or an integrated science master's degree with subjects such as physiology, applied physics, human biology, and engineering relevant to CN. These courses include modalities such as EEG, EMG, and NCS, whereas sleep modalities fall under respiratory physiology and sleep sciences (National Health Services 2019; Middlesex University London 2023). Neurophysiology and respiratory physiology professions are regulated by the Health and Care Professions Council in the UK and any practitioner in these fields must be registered (HPCSA 2023).

With the exception of sleep investigations, the UK professional education, regulation, and scope of practice of CN clinical scientist are the most closely related to our model of B Tech and BHS CNP in South Africa. Mr Brett Sanders who obtained his N Dip and B Tech from the CUT (Health Professions Council of South Africa 2023a) is currently the Lead Consultant Clinical Scientist in Intraoperative Neurophysiology and Department of Clinical Neurophysiology at Cleveland Clinic in London (LinkedIn Corporation 2023).

2.9 Conclusion

In conclusion, it is apparent that the CT and CN TLA pathway is rich in history and development, but not in structured learning or WIL organisation. As noted by du Plessis (2019), Ngwane (2016) and Holdsworth, Watty and Davies (2009), stakeholder involvement in the structuring of an organised and industry directed WIL experience is important to the success of any such programme. Both the higher education institutions and WIL providers should understand the needs and perceptions of the students to realise the aims of the programme (Ngwane 2016). It is also important to consider methods of WIL that integrate students in the WIL placement in a way that promotes a feeling of belonging and prevents students from feeling isolated from peer support (McBeath, Drysdale and Bohn 2018).

CHAPTER 3: RESEARCH METHODOLOGY, DESIGN AND METHODS

This chapter provides an in-depth discussion on the development of the research concept, research question, research methodology, and analysis.

The Delphi research method and available consensus analysis measures chosen for this research are reviewed. The development and content of the survey instruments are discussed in relation to the measures of consensus chosen for data analysis.

3.1 Introduction

The purpose of this study was to identify the core testing modalities, and embedded graduate skills and attributes, that must be included in undergraduate CNT training to fulfil minimum practice requirements for the South African context (Table 1.1).

Individual CN training units follow the prescripts of individual UoTs' WIL training models. This study aimed to propose a standardised delivery of work integrated learning (WIL) education for all three UoTs. This study investigated how standardised CNT WIL content can be structured to fulfil industry core modality requirements, at appropriate outcome skills levels, during training at units of all three UoTs.

The Delphi research method was chosen as an iterative multistage process that can be used to combine opinions and ideas from a group of expert participants from a defined specialised field (Hasson, Keeney and McKenna 2000). This research method has been used in study areas where knowledge regarding the subject under investigation is incomplete, or where a scarcity of previous research investigations exists (Skulmoski, Hartman and Krahn 2007; Marsh-Nation 2019). The Delphi method has been successfully used in widely diverse fields of research and is popular in various healthcare related fields, including clinical medicine, medical and nursing education related research, as well as EEG (Akins, Tolson and Cole 2005; Holey *et al.* 2007; Marsh-Nation 2019).

The project outline is summarised in Table 3.1. Each step is discussed in this chapter.

Table 3.1: Project outline

Step 1 **Identification of the problem:** Lack of understanding of requirements for standardised WIL training in CN to equip graduates for integration into private practice.
Step 2 **Defining the concept:** Use of expert opinion from CN practitioners to define WIL requisite training requirements and graduate skills
Step 3 **Research method identification:** Delphi is an iterative process used to present a panel of experts with a topic of uncertainty or to gather information regarding a question that is unknown. It is a process of controlled feedback and is used to present the panel with findings of previous rounds and testing panel agreement on the group opinion in the previous round/s.
Step 4 **Ethics approval (Appendix 1):** The concept was presented to the Durban University of Technology Clinical Technology Departmental Research Committee. After approval the concept and research proposal were approved by the Faculty of Health Sciences Research Committee for further development of a research proposal to be submitted to the DUT Institutional Research Ethics Committee for approval. Full ethics approval was obtained before recruiting a panel of expert clinical neurophysiologists to complete an initial anonymous electronic questionnaire.
Step 5 **Literature review and first round of data gathering:** Investigating the history of CT training and the CN profession in South Africa through literature review of past training documents and personal communications.
Step 6 **Second round of data gathering: first questionnaire (Q1) (Appendix 5):** Development and administering of the Q1. Descriptive statistics and agreement analysis of ordinal data. Thematic analysis of qualitative data.
Step 5 **Third round of data gathering: second questionnaire (Q2) (Appendix 6):** Development and administering of the second questionnaire (Q2) Controlled feedback on aggregate data from Q1 with consensus building rephrasing of ordinal questions. New questions arising from Q1.
Step 6 **Analysis of quantitative data from Q1 and Q2, defining requisite skills and experience, modality linked and general. Determining modality inter-dependency for learning.**
Step 7 **Development of the WIL training content framework.**

This research initially focused on gathering information regarding historic and current CN WIL education in South Africa. Additional qualitative inputs from CNPs in private practice were solicited using an online Delphi survey questionnaire (Q1) with open-ended questions (Tapio *et al*. 2011). All expert inputs were considered and used to design a second Delphi survey questionnaire (Q2). The expert opinions of CNPs in CN training units were invited during Q2 due to their knowledge and experience in WIL provision.

By combining the knowledge, skills, and experiences of these individuals the study sought to find existing consensus regarding the current minimum training industry needs, and the interrelated skills learning needed to support student training to combine into a cohesive WIL content framework (Robinson 2018).

The CNP private practitioners were included for their expertise on the principal outcome requirements for adequate patient care and diagnostic services needed directly upon graduation. The WIL providers were included to give context regarding the training requirements to achieve the desired outcomes. Their combined expertise was expected to provide clarity on general graduate attributes required for achieving these learning outcomes.

3.2 Identification of the problem: concern regarding work-integrated learning in clinical neurophysiology

Positionality of the researcher:

The researcher has been involved with clinical and theoretical instruction in one or more CN modality since 2001, both in South Africa and internationally. In 2015 she was appointed as CN unit manager of an accredited training unit and has been involved with training of clinical CNT CT students KT-S for two of the three South African UoTs. She was a member of the 2016 CNSSA education committee involved in the design of a proposed curriculum for the new BHS degree. She served as part-time category specialist lecturer between 2017 and 2020 and had a front row seat and active involvement with roll-out of the new BHS degree at both DUT and TUT because some of the first CNT BHS KT-S from both universities trained in the unit she manages. As an industry representative for DUT, she participated in the DUT workshop on operationalisation of the BHS CT degree held at the DUT Ritson Campus from 16 to 17 May 2016. In 2019 the researcher became involved in the TUT advisory board on CN WIL implementation for the BHS. Additionally, she has been involved with training of EE students registered with the HPCSA and enrolled in the CNSSA EEG technician course.

Nature of the concern:

In each of these roles a recurrent theme of concern between all categories of CT, and especially in CNT, was that of a disconnection between WIL training outcomes and industry requirements. From advisory board meetings, BHS implementation meetings, CNSSA education and training meetings, and industry complaints, it became apparent that a standardised CN WIL content framework should be supplied to UoTs and training units to assist with graduates' integration into private practice, especially with the decrease in clinical training time of the BHS degree.

3.3 Research topic

The research topic was distilled through discussions at CNP professional meetings, UoT advisory board meetings dealing with course development of the BHS, and BHS implementation workshops. The viability and validity of the highlighted concerns were further emphasised at the CNSSA annual general meetings between 2016 and 2018. First formulation of the research topic and realisation of the need for the study was determined after presentation of the progress on the BHS implementation at the 2018 CNSSA annual congress.

3.4 Institutional ethics approval

Research concept approval was obtained from the DUT CT Departmental Research Committee in 2019 after which protocol development was finalised. After approval of the Faculty of Health Sciences Research Committee the research protocol was submitted to DUT Institutional Research Ethics Committee for consideration.

Provisional ethics approval was received in February 2021 and gatekeeper permission requested from the CNSSA to use a deidentified database of contact email addresses for distributing the online questionnaires (Appendix 2).

Final full institutional ethics approval from the DUT Institutional Research Ethics Committee was obtained in May 2021 (Appendix 1) and the first questionnaire (Q1) was distributed in December 2021.

3.5 The Delphi research method

The Delphi method of research, sometimes referred to as a process due to the iterative design, has a long history in decision making research. Beiderbeck *et al.* (2021) describe Delphi as a scientific method to "organize and structure an expert discussion aiming to generate insight on controversial topics with limited information". Linstone and Turoff (1975) describe the Delphi method as a structured anonymous group communication process that is flexible and customisable and can be used to facilitate group problem solving. Skulmoski, Hartman and Krahn (2007) concluded that there is no "typical" Delphi. Each researcher modifies the method to suit the circumstances and research question. In conventional research there has been a divide between quantitative and qualitative methods, whereas with a Delphi study the researcher can combine the strengths of both.

A Delphi study provides an opportunity to achieve a more complete understanding of the data by incorporating both a qualitative gathering of knowledge (expert opinion) followed by a quantitative evaluation of the validity of these opinions (Iqbal and Pipon-Young 2009).

The Delphi research method has been successfully used in widely diverse fields of research, including clinical medicine and medical education (Akins, Tolson and Cole 2005), as well as education in EEG (Marsh-Nation 2019). Sitlington and Coetzer (2015) reported that the Delphi method has assisted in the development of clinical guidelines and nursing practice guidelines. They proposed that the process could easily be adapted to other allied health disciplines. A search through the ProQuest® digital dissertations database revealed at least 280 dissertations and theses that used the Delphi method in their research. The majority of this research was from either education or healthcare. As this current research is addressing WIL education in CN – a healthcare field – the Delphi technique was considered especially suitable.

One of the main characteristics of a Delphi study is anonymity amongst participants with controlled feedback of group opinion between the researcher and the participants. This feedback consists solely of the consolidated statistical group response and expert input received, keeping the individual inputs confidential (Hasson and Keeney 2011; Trevelyan and Robinson 2015). This anonymity allows the participants to freely express their opinions without influence from other participants. This influence can be direct or indirect and anonymity allows each participant to evaluate their decisions on the merit of the idea or proposal, rather than on who has proposed the idea (Skulmoski, Hartman and Krahn 2007; Barrett and Heale 2020).

While a Delphi study can take an approach that is primarily qualitative or primarily quantitative (Marsh-Nation 2019) the focus of this study was finding a quantitative solution to clinical skills training in CN through using expert opinion in building a WIL learning framework. In this type of “explorative” or “investigative” Delphi process the first questionnaire is usually created by the researcher following a detailed literature review, consultation with relevant individuals and consideration of the aims of the study, as was the case in this research (Mullen 2003; Iqbal and Pipon-Young 2009; Beiderbeck *et al.* 2021).

As an alternative to conventional surveys a Delphi study allows for interaction with the participants, especially where the first questionnaire is open-ended, and the participants are directly involved in determining the course and outcome of the research (Mullen 2003).

According to Iqbal and Pipon-Young (2009), the more open-ended the first questionnaire the better. Such a questionnaire involves a series of open-ended questions inviting participants to brainstorm anonymously. The second questionnaire is then constructed from the data gathered from the open text input obtained through the first questionnaire. This second questionnaire commonly uses a quantitative, ‘tick box’ style survey using Likert (1932) type agreement scales or ranking scales (Iqbal and Pipon-Young 2009).

In a Delphi design where the first round is open-ended, a minimum of three rounds may be needed to allow feedback and revision of responses. However, several recent health-related studies have successfully employed an open-ended first round with only one further round (Mullen 2003).

The scarcity of research in the field of CT in South Africa coupled with the lack of documented WIL structure in CT and CN in particular became apparent from the literature review during the research concept design. Therefore, a study design had to be chosen that could incorporate the knowledge and expertise of CNPs, in both training and industry sectors of the profession, as the foundation for a quantitative framework built upon multiple interdependent modalities in CN (Yousuf 2007).

Since no previous investigation in this field in South Africa had occurred it was determined that a fully anonymous Delphi study with an explorative first questionnaire, and a decision-making second questionnaire would best suit the aims of the research (Day and Bobeva 2005).

3.6 Research method selection

Research concept approval was obtained from the DUT Department of Clinical Technology Research Committee in 2019 after which the researcher started with background research. A literature review yielded three South African manuscripts dealing with assessment and training in CT (Human 1996; Mohapi 2017; Ali-Musa *et al.* 2018). None of these were directly related to CN. The lack of published literature led to the need to discuss development of the profession with pioneers in the development of the profession of CT and the category of CN. Clinical technology and CN category pioneers were contacted through email requesting interviews for the study. These interviews yielded historical information and guidance on current challenges and concerns required for determining the final study design.

The anonymity of the Delphi research method provides an opportunity for participants to provide novel information not otherwise known to the researcher. This characteristic was valuable to the success of this research due to the small number of CNPs and perceived dichotomous views.

After consideration of various qualitative and quantitative research methodologies the researcher realised that a quantitative explorative decision-making Delphi study, incorporating initial open-ended questions, was the only feasible research process to achieve the aims of the project. Qualitative information regarding the current state of CN had to be sourced from those actively involved in CN practice in South Africa. This was followed by statistical aggregate response analysis to allow for quantification and interpretation of the qualitative research data (Skulmoski, Hartman and Krahn 2007) generated by Q1 (Tapio *et al*. 2011).

3.6.1 Number of questionnaires and participant feedback

Feed-back to participants and the opportunity to revise earlier responses are seen as one of the defining features of the Delphi process and requires at least two rounds of questionnaires (Mullen 2003). In a study with a homogeneous sample sufficient information, or consensus, can be reached with fewer than three rounds (Skulmoski, Hartman and Krahn 2007). The Delphi design of providing feedback to participants is believed to give participants a sense of ownership of the outcome due to active participation in the research (Boel *et al.* 2021). Controlled feedback informs the participants of the other participant's perspectives and provides the opportunity for Delphi participants to clarify or change their views. This involvement of participants in the development of the outcome increases the acceptance of the findings (McKenna 1994).

The use of feedback aims to keep participants' interest between rounds through insight into the findings from the previous round, often given as the median response of the participant panel and compared to their own responses (von der Gracht 2012; Marsh-Nation 2019). In this study the characteristic of anonymity of answers and opinions was the most important feature. Personal feedback at the conclusion of the round would have required the researcher to be unblinded to the identities of individual answer sets. Beiderbecke *et al.* (2021: 1) described Delphi research as a scientific method to "organize and structure an expert discussion aiming to generate insight on controversial topics with limited information". Due to the well-known status of the researcher, it was necessary to include additional blinding of the researcher to the identities of participant data. This was done by using the QuestionPro® (QP) online survey software respondent anonymity assurance® (RAA) function. This function generates a unique response identification number and QP assert that the survey researcher will not have access to both the respondent's email address as well as the response data at the same time. To overcome the personal feedback limitation created by use of RAA, another QP function was used. The online software auto generates a research report containing participants responses in comparison to cumulative group answers at the time of completion of the questionnaire. This is called a spot-light report® (SLR) (Appendix 7). All participants that completed the online questionnaires received a SLR report generated by QP upon completion. These reports contained preliminary data analysis of the group aggregate responses. These reports also indicated the participant's response correlation with the group response. In addition, participants received an email thanking them for participation (Appendix 3) together with their personal complete answer set as an attachment (Appendix 4).

Additional feedback of group majority opinion was given as part of follow-up questions during Q2 round. Participants had the ability to review their personal answers and SLR for comparison of group opinion. In this way participants could review their original answers with consideration of the group opinion before answering the follow-up questionnaire.

3.7 Study setting

The study was set in the private CN industry in South Africa, where graduates need to integrate upon qualification; and the accredited WIL units responsible for achieving desired training objectives.

3.8 Study population and sampling

The study population included all CN practitioners currently registered with the HPCSA RCT. These include CNPs of all past and present CN training programmes from all UoTs, namely the different models of N Dip training, the B Tech programme, and the current BHS. No distinction was made between age, gender, or type of registration (supervised, independent, or private practice). It is important to note that the industry reality of a CNP registered as either independent practice or private practice is the same. Private practice registration is purely indicative of a BTech qualification, whereas N Dip graduates up to 2001 without a B Tech qualification were categorised as independent practice registration (Health Professions Council of South Africa 2013). With the BHS qualification this distinction will be removed and all qualified CNPs will be registered under independent practice.

Questionnaire 1 was not available to CNPs with no private practice experience as the context was determining private practice industry needs. Questionnaire 2 dealt with the required embedded knowledge and skills needed to achieve industry outcome needs and all qualified CNPs were invited to participate without regard for private practice experience.

3.8.1 Sampling for the initial expert interviews

Purposeful sampling was used for selecting pioneer CNPs, CT educators, and other individuals with historic experience in the development of CT and CN in South Africa (Beiderbeck *et al*. 2021). These individuals were approached via email for background interviews.

3.8.2 Sampling and sample size for online questionnaires

Akins, Tolson and Cole (2005) summarised findings around previously used panel sizes and response rates. From their work it is evident that few studies publish the initial response percentage in comparison to the number of first round responders or the number of invitations sent out. According to Okoli and Pawlowski (2004) it is more important for the participant sample to have a deep understanding of the issue than to be a statistically representative sample of a greater population. Birko, Dove and Ozdemir (2015) examined the influence of panel size on outcome consensus measures and showed minimal effect on the results of a panel of less than ten or up to 50. Beiderbecke *et al.* (2021) recommended a panel size of between 15-20 experts.

- No minimum or maximum sample size was set for this study, although the researcher did aim for a relatively large participant group of between 20 and 30 final participants for a more holistic view of the data (Day and Bobeva 2005; Skulmoski, Hartman and Krahn 2007; Beiderbeck *et al.* 2021; Nasa, Jain and Juneja 2021).
- Non-parametric sampling using self-sampling, or volunteer sampling, with exclusion criteria was used to recruit participants to answer the online questionnaires (Nikolopoulou 2022). Snowball sampling was used to potentially increase the volunteer sample size (Santaguida *et al.* 2018).
  - Although purposeful sampling was used during the initial interview the two questionnaire rounds aimed for a more diverse participant group for better decision-making performance (Boulkedid *et al.* 2011).

Self-sampling was achieved by inviting all individuals whose email addresses were listed in the CNSSA contact database to access Q1. Snowballing was achieved by allowing invitees to forward the invitation to other interested CNPs who could request a participation link.

Random sampling was not possible as not all CNPs' contact details were accessible to the researcher and not all contacts in the CNSSA database would fit the inclusion criteria. Contacts had the ability to unsubscribe from the list for future reminders and invitations.

3.9 Inclusion and exclusion criteria

Separate inclusion criteria were set for Q1 and Q2 because of the different aims of the two questionnaires. The aim of Q1 was to investigate current needs in the South African CN industry using both closed and open-ended questions. The aim of Q2 was to determine the educational requirements for a WIL framework, quantitatively, to accomplish those goals through closed questions.

3.9.1 Initial interview inclusion and exclusion criteria

1. Individuals involved in the development of CT and CN education in South Africa.
2. First generation registered CNPs and current academic unit managers.
3. Persons who did not consent to interview or did not fulfil the inclusion criteria were excluded.

3.9.2 Q1 inclusion and exclusion criteria

1. All HPCSA registered CNPs with private practice experience were allowed to contribute answers to Q1.
2. Individuals not registered with HPCSA, KT-S registrations, and registered CNPs with no private practice experience were excluded.
3. Training experience was not a consideration.

3.9.3 Q2 inclusion and exclusion criteria

1. All HPCSA registered CNPs were allowed to contribute answers to Q2, including those without private practice experience or who missed participation in Q1 (Boel *et al.* 2021).
2. Individuals not registered with the HPCSA, and KT-S registrations were excluded from participation.
3. Persons with training experience were desirable.

3.10 Prelaunch questionnaire testing for the online questionnaires

After questionnaire development pilot testing of the questionnaire flow and question structure was performed. Questionnaire distribution was tested by sending test invitations to twelve email addresses of five individuals. Addresses hosted through both free and enterprise email providers were targeted. Any problems in the questionnaire distribution, question phrasing, or logical flow of questioning were assessed and the QP anonymity assurance function was tested. The automated response data set generation and analysis functions of the QP platform was tested and any problems that arose were addressed with the survey provider. Two retired CNPs, one neurologist, and two CN students were recruited to participate in the pilot study. A total of 20 test data sets were generated per questionnaire. Data from Q1 and Q2 the pilot studies were not included in the final data sets.

3.11 Data collection

Traditionally a Delphi study consists of three or more rounds of data gathering. In this study the researcher decided on a first round of data gathering in the form of literature review and initial expert interviews, followed by two iterative rounds of questionnaires. After reviewing the findings of Diamond *et al.* (2014) it was decided that consensus on more than 75% of measures, or stable dissensus, at the end of Q2, would determine the need for a third questionnaire.

If more than 75% of consensus items reached the consensus or dissensus threshold, or consensus of responses between rounds increased or remained stable, a third questionnaire would not be necessary. Linstone and Turoff (1975) defined response stability as a less than < 15% change in responses between rounds.

The online survey programme QP was used for setting up and distributing and then initial data analysis of the questionnaires. Participant feedback was managed using the QP dashboard. Participants accessed the questionnaire through a unique one-user link connected to the email address that received the invitation. Multiple sessions were allowed for completion of the questionnaire.

Participants received up to four reminders of uncompleted questionnaires via the email address they indicated upon saving the questionnaire. All links that were not accessed also received up to four reminders.

To achieve a model of WIL to serve CNP training using a Delphi study design it was imperative to first determine the industry directed outcome goals prior to determining interdependency of modalities. This interdependency of modalities was then used to structure a modality content framework for WIL in CN.

In the absence of an established body of knowledge to measure consensus or dissensus it was decided to do an investigative exploratory first round of data collection. This was done through interrogating the existing available education documents and conducting unstructured interviews. Clinical neurophysiologists in training units and independent private practice were interviewed to compile a list of testing modalities historically expected of both N Dip and later B Tech graduates. Questionnaire 1 was compiled using existing course subject module descriptors, study guides, SAQA documents, personal training documents, and personal communication interviews.

3.11.1 Round one data gathering: Initial expert interviews

Unstructured interviews were conducted in a conversational manner allowing participants to freely share their knowledge and recollections. Handwritten notes and voice recordings were used for record keeping after obtaining consent from the interviewees.

These interviews formed the foundation of the first round of the research and included CT and CN training pioneers. Further training pioneers, and early generation CNPs, who were known to the researcher or identified through these interviews were also contacted. An attempt was made to contact persons from all major training centres. Acceptance of a written request for interview and further verbal informed consent for recording of conversations was obtained. A limitation was that not all individuals were available for interview and the prior passing of some individuals identified for interviews. Documentation regarding the origin and formation of the profession of CT and subsequent category of CN was sought through literature review of documentation obtained from UoTs offering the course, HoDs and lecturers from the different UoTs involved, previous HPCSA professional board members, and founding members of the original professional society.
Source literature on the history and development of CT and CN was requested from all three UoTs and current and past professional board members.

3.11.2 Round one data gathering: literature review

An online literature search was conducted for related research in CN and WIL education. Initial literature review was conducted using the DUT library e-resources and QuickFinder® search function. Further searches of the ProQuest dissertation database, PubMedCentral, National Library of Medicine, MedLine, SAGEJournals, Taylor & Francis Online, Biomed Central, and JSTOR were performed. Broad internet searches were also conducted using major web browsers and GoogleScholar®. Search terms included: “clinical technology”, “clinical neurophysiology”, “neurophysiology education”, “work learning neurophysiology South Africa”, “EEG education”, “electroneurodiagnostic training”, “work integrated learning”, “work integrated learning in South Africa”, “WIL”, “WIL and WEL in clinical technology health science”. Individual CN test modality names were paired with either WIL”,” WEL”, “on the job training”, “learning”, “experiential training” or “education”. Search terms were paired with “history” and “history in South Africa” for biographical information. Information on international CN training was obtained by using these search terms paired with “international training”, “international education”, “international registration requirements”. Additional searches using “healthcare framework design”, “Delphi”, “Delphi research”, “Delphi method” was performed. Further literature material was sourced from article references and where possible primary source articles/publications were consulted for accuracy. No date limits were set for any of the searches.

Individuals known to the researcher as having been involved in the development of CNT in South Africa were contacted for interview and access to their personal historical written records. Through these contacts the researcher was introduced to further pioneers and gained access to hardcopy literature including course concept documents, meeting minutes, and original scope of practice and profession documentation. Further information regarding historical and current WIL programme designs was obtained from authors of literature and individuals identified through written records or from initial interviews. Several members of the original professional society and board were contacted. Further interrogation of the current CN education standards (course and subject module descriptors) at various academic institutions and clinical training units, including the author's own unit, were reviewed.

3.11.3 Round two data gathering: Q1

The first anonymous Delphi survey questionnaire, Q1, was developed from the information gathered from the interviews and interrogation of current and historical documents. Interview information was cross-referenced between individual interviews and verified through correlation with the available and newly received written records. The resulting questionnaire included both quantitative and open-ended questions.

The QP survey distribution service was used to anonymously recruit participants through email using the CNSSA contact list. Each invitation contained a pre-populated link to the survey based on the participant's email address (Beiderbeck *et al.* 2021). The email invitations contained an assurance of anonymity through the QP RAA. Assurance was provided that their contact email address would only be used for invitations and reminders. Participants could insert an alternative email address for future contact or use the unsubscribe link.

Clinical neurophysiologists in private practice were identified through demographic questions and all contacts not fulfilling the inclusion criteria were automatically excluded by termination branching of the electronic questionnaire. Participants whose questionnaire was terminated received a thank you message informing them that they may be contacted for the follow-up questionnaire and offering the opportunity to unsubscribe from future invitations.

The main aim of Q1 was to explore private practice industry requirements for graduates to integrate smoothly upon graduation and test whether an existing consensus could be identified on the skills, knowledge and attributes KT-S must possess to function outside of the training unit upon graduation either nationally or internationally – i.e., determining training needs.

3.11.3.1 Development of the first Delphi Questionnaire (Q1)

The researcher determined that a Delphi study with a mostly open-ended first questionnaire would best suit the aims of the research. Since there was no previous investigation in this field in South Africa, additional data needed to be generated through qualitative open-ended questions (Tapio *et al.* 2011). The questionnaire tested for existing consensus regarding essential modalities and modality related outcome skills levels through quantitative tick-box selection questions. Further information on basic skills and knowledge was sought through open-ended questions and consensus reported.

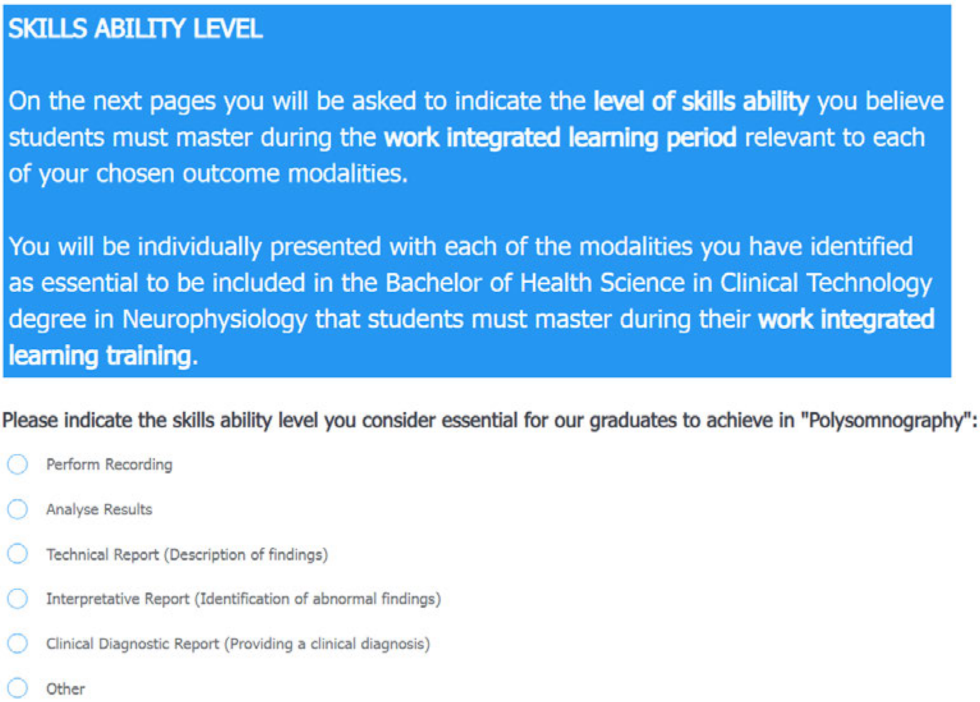
The first consensus-testing question was a rank order multi-voting question testing agreement with undergraduate inclusion of the test modalities identified from the training documents. A consensus test of non-weighted multi-voting was decided upon to test or assess the level of consensus existing in the profession regarding essential course modality outcomes.

The tick box style “multi-vote voting” method giving each participant 10 “votes” was chosen to test whether consensus existed regarding modalities considered essential to an undergraduate WIL course. Each participant was presented with the list of 23 identified outcome modalities in a randomised order. This was done to limit order bias whereby items at the top and bottom of a list receive more votes. Each participant was invited to select up to ten modalities from the 23 identified in the literature. The selections made here customised the rest of the questionnaire to each participant. Participants had an option to add a modality not listed.

The rest of the questionnaire was presented in four questionnaire question blocks. Each block presented the participant's individual modality choices back to the participant in alphabetical order for further investigation.

The first was for the selection of their expert opinion regarding the required exit level graduate skill level. The second, third and fourth were qualitative opinion gathering questions. Participants were asked to contribute test statements identifying up to five theoretical skills, practical skills, and graduate attributes required for mastering each of their chosen modalities.

The first question block consisted of select-one tick-box questions. This block was considered the second quantitative question. Participants were allowed to select requisite graduate outcome skills level for each of their personal modality choices. Participants were asked to indicate the outcome skill (OSL) level required to be reached for graduates to be considered sufficiently proficient to practice in industry immediately post-graduation (Figure 3.1).


SKILLS ABILITY LEVEL

On the next pages you will be asked to indicate the **level of skills ability** you believe students must master during the **work integrated learning period** relevant to each of your chosen outcome modalities.

You will be individually presented with each of the modalities you have identified as essential to be included in the Bachelor of Health Science in Clinical Technology degree in Neurophysiology that students must master during their **work integrated learning training.**

Please indicate the skills ability level you consider essential for our graduates to achieve in "Polysomnography":

- Perform Recording
- Analyse Results
- Technical Report (Description of findings)
- Interpretative Report (Identification of abnormal findings)
- Clinical Diagnostic Report (Providing a clinical diagnosis)
- Other

Figure 3.1: Graduate outcome skill level selection question
Participants selected the most appropriate choice of highest outcome level from predefined options. There was an open text "other" option to contribute qualitative statements.

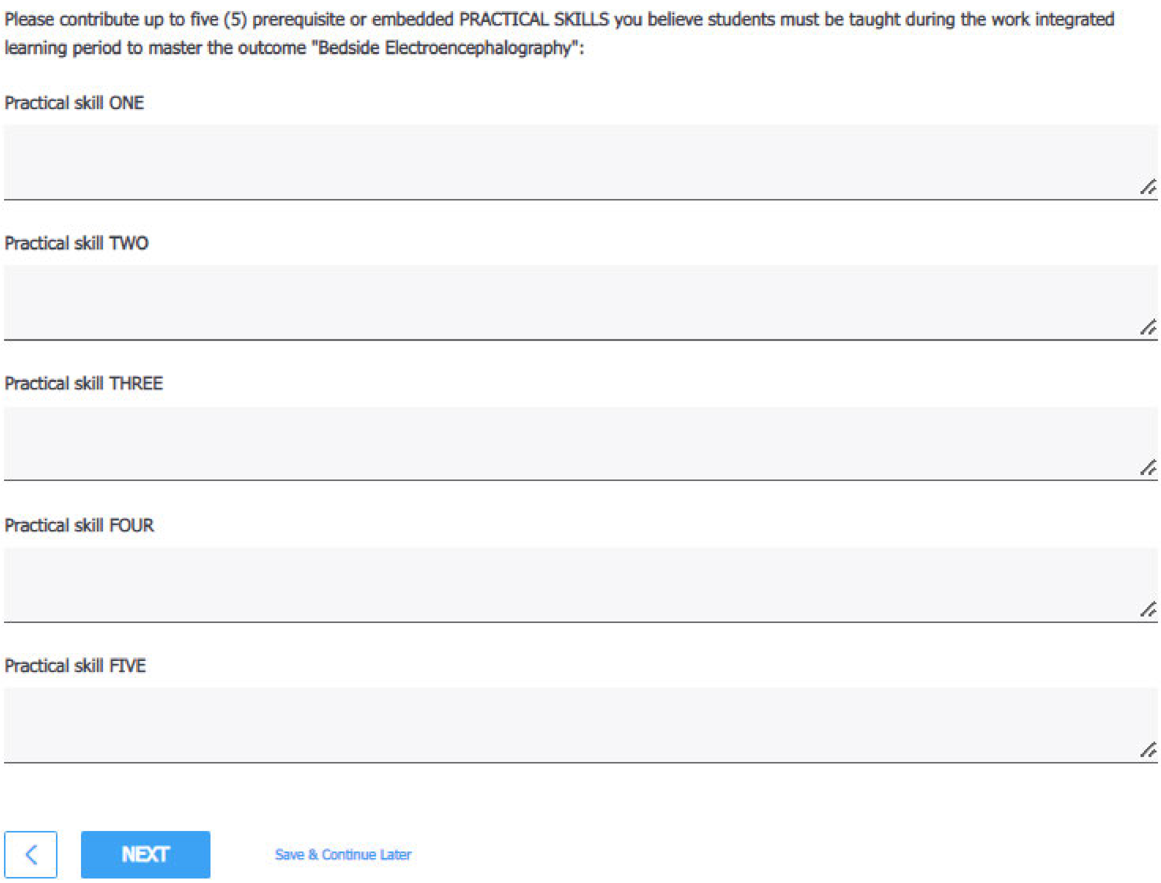
Each level of skills ability was taken as inclusive of all lower levels and an "other" option was provided for additional information (Figure 3.1). For example, "Analyse results" would mean the graduate should both be able to record and analyse the recorded results. Similarly, "Clinical Diagnostic Report" would include the performance, the analysis, ability to describe technically, ability to interpret normal and abnormal, and ultimately to provide a clinical correlation to the results of the recording.

The next three sections of the questionnaire consisted only of qualitative open-text questions. All modalities that were selected by at least one participant for inclusion in a four-year undergraduate degree were analysed for embedded knowledge, practical, and graduate attribute skills. In each section participants were presented with questions related to their own modality selections.

In turn, participants were asked to contribute up to five embedded prerequisite practical skills, knowledge skills, and graduate attributes for each of their modality selections. Figure 3.2 shows an example of one of the section headers that contained the general question phrasing and Figure 3.3 shows the participant answer screen for entering of expert opinions.

PRACTICAL SKILLS
On the next pages you will be asked to contribute **up to five (5) prerequisite or embedded PRACTICAL skills** you believe students must be taught during the **work integrated learning period** to master each relevant outcome modality.
You will again be individually presented with each of the modalities you have identified as essential to be included in the Bachelor of Health Science in Clinical Technology degree in Neurophysiology that students must master during their **work integrated learning training**.

Figure 3.2: Example of skills question section header


Please contribute up to five (5) prerequisite or embedded PRACTICAL SKILLS you believe students must be taught during the work integrated learning period to master the outcome "Bedside Electroencephalography":

Practical skill ONE

Practical skill TWO

Practical skill THREE

Practical skill FOUR

Practical skill FIVE

NEXT

Save & Continue Later

Figure 3.3: Example of open-ended skills questions

3.11.4 Round three data gathering: Q2

The anonymous Delphi survey questionnaire, Q2 formed the third round of data gathering. Results of Q1 tested whether an existing consensus could be identified for developing Q2 as a quantitative rating and selection questionnaire. During Q2 participants were asked to rate agreement with, and rank the importance of, information obtained from Q1 participants.

Email invitations to participate in Q2 were sent to all email addresses in the QP database after closure of Q1. This excluded those that chose to unsubscribe and included additional contact addresses provided by participants of Q1. A model of “all-rounds” participation invitation was used in order to ensure good representation of opinions and prevent false consensus through exclusion of valid input from potential participants (Boel *et al.* 2021).

Health Professions Council of South Africa registered CNPs were identified for participation through demographic questions. Students and non-CNPs were automatically excluded based on initial demographic questions and the questionnaire automatically terminated. All terminated questionnaire participants received a message thanking them for their interest in participation.

The aim of Q2 was multi-fold:

- Firstly, to confirm rank order importance of the 16 modalities and test consensus on inclusion in an undergraduate BHS.
- The second aim was to determine modality interrelation for learning through a set of questions asking participants to select and rank related modalities. Modalities were ranked according to dependence on prior knowledge of the modality under investigation or as prerequisites for mastering the specific modality under investigation (Figure 3.4).
- The third aim of the questionnaire was to test consensus on modality relationships to the duties and functions of a KT as described in Human's dissertation (Human 1996).
- The fourth aim of the questionnaire was to determine the outcome year (three or four) for mastering these duties or functions and either basic competency or advanced proficiency in each modality as described in Section 3.13.1.2.
- The fifth aim of Q2 was to determine the importance of, and outcome year for, the knowledge items contributed during Q1.

3.11.4.1 Development of the second quantitative Delphi survey

During data analysis of Q1 a total of 15 test modalities passed initial criteria for inclusion in an undergraduate BHS and one potential additional modality was added. These 16 modalities were further investigated in Q2. Questionnaire 2 responded to all the items participants contributed during Q1 open-ended questions.

Questionnaire 2 comprised several question types including category selection, rank-order, and Likert scale importance rating questions.

Each question type used is described below.

3.11.4.1.1 Rank order of learning importance

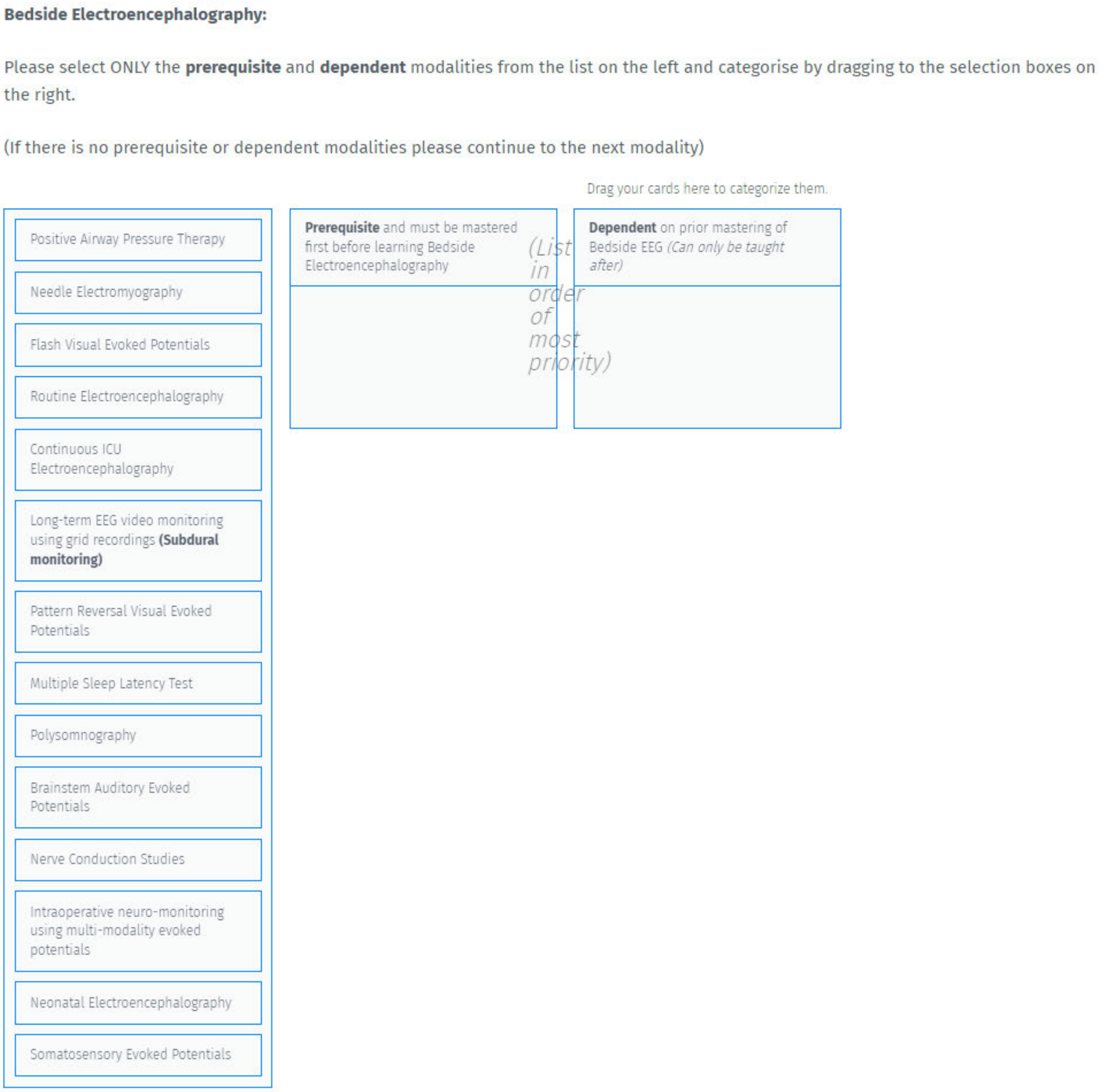
Weighted rank order was used to test the 16 CN testing modalities identified as essential for inclusion in the BHS WIL framework. Modalities were displayed in randomised order to eliminate listing bias. Participants were asked to reorder the modalities listed in order of importance for learning. They were also asked to omit any modalities they did not consider essential.

3.11.4.1.2 Inter-modality dependency framework questions

Each modality was presented individually for critical consideration on inter-modality relationships as either pre-required knowledge or dependent on another modality, as shown in Figure 3.4.

Participants were presented with a list of the 16 modalities from Q1 (Figure 3.4) and asked to select related modalities and list each modality as either dependent on prior knowledge of the modality under investigation, or as a prerequisite for learning the modality under investigation. Participants were also asked to rank the related modalities in order of priority.

These questions were aimed at determining modality learning relationships for the practical part of the WIL modality content framework through identification of the foundational modalities, and their related dependent, and likely more advanced, modalities.


Bedside Electroencephalography:

Please select ONLY the **prerequisite** and **dependent** modalities from the list on the left and categorise by dragging to the selection boxes on the right.

(If there is no prerequisite or dependent modalities please continue to the next modality)

Drag your cards here to categorize them.

- Positive Airway Pressure Therapy
- Needle Electromyography
- Flash Visual Evoked Potentials
- Routine Electroencephalography
- Continuous ICU Electroencephalography
- Long-term EEG video monitoring using grid recordings **(Subdural monitoring)**
- Pattern Reversal Visual Evoked Potentials
- Multiple Sleep Latency Test
- Polysomnography
- Brainstem Auditory Evoked Potentials
- Nerve Conduction Studies
- Intraoperative neuro-monitoring using multi-modality evoked potentials
- Neonatal Electroencephalography
- Somatosensory Evoked Potentials

Prerequisite and must be mastered first before learning Bedside Electroencephalography *(List in order of most priority)*

Dependent on prior mastering of Bedside EEG *(Can only be taught after)*

Figure 3.4: Modality inter-dependency for learning question, Q2

3.11.4.1.3 Final graduate outcome skills levels

Each participant was presented with the group majority OSL selections from Q1. They were asked to rate their agreement with Q1 ratings by either selecting a higher or lower level of required proficiency or by selecting the Q1 group score (Figure 3.5). This re-rating also afforded participants an opportunity to change their Q1 selection.

Participants could select non-applicable (N/A) for any modality they believed should be excluded from undergraduate WIL.

The skills outcome selection question was rephrased for clarity and consistency between all modalities, and outcome level choices were presented on a five-point Likert scale rated from non-applicable to complete proficiency in reporting with clinical correlation (Figure 3.6).

GRADUATE OUTCOME SKILLS LEVELS

Next you will be presented with graduation level outcomes per modality.

The **BOLD TEXT** next to the modality name is the **group** selection **result** from Questionnaire One.

Please do ONE of the following:

1: If you **agree** with the outcome level please **indicate** your **agreement by selecting the same outcome level** as is shown in **BOLD** next to choice the modality name.
OR
2: If you do not agree please select an the outcome level you believe graduates must **achieve at** the **end** of their **WIL** period.
OR
3: Select **N/A** if you believe any of the **modalities** may or should be **EXCLUDED in undergraduate WIL.**

NOTE: Please keep answers limited to the WIL period of 18-20 months.

Figure 3.5: Skills outcome question instructions Q2

Please indicate the final level of skill a student must master at the end of their WIL for graduation:

Select **N/A** if you believe any of the modalities may or should be **EXCLUDED** in undergraduate WIL.

Indicate your **agreement** by **selecting the same outcome level as is shown in BOLD**
Select One

	ONLY PERFORM Recording	**DESCRIBE report** Perform, Analyse and write a technical **descriptive report** (describe the findings in comparison to known patterns or values)	**INTERPRETATIVE report** Perform, Analyse and write an **interpretive report** (Classify results according to pathological implication without clinical correlation)	**CLINICAL correlative report** Perform, Analyse and write a **clinical correlative report** (Suggest a clinical diagnosis or make recommendations)	**N/A**
Nerve Conduction Studies **(INTERPRETATIVE)**					
Somatosensory Evoked Potentials **(INTERPRETATIVE)**					
Brainstem Auditory Evoked Potentials **(INTERPRETATIVE)**					
Pattern Reversal Visual Evoked Potentials **(INTERPRETATIVE)**					
Flash Visual Evoked Potentials **(INTERPRETATIVE)**					

Figure 3.6: Outcome skills level question Q2

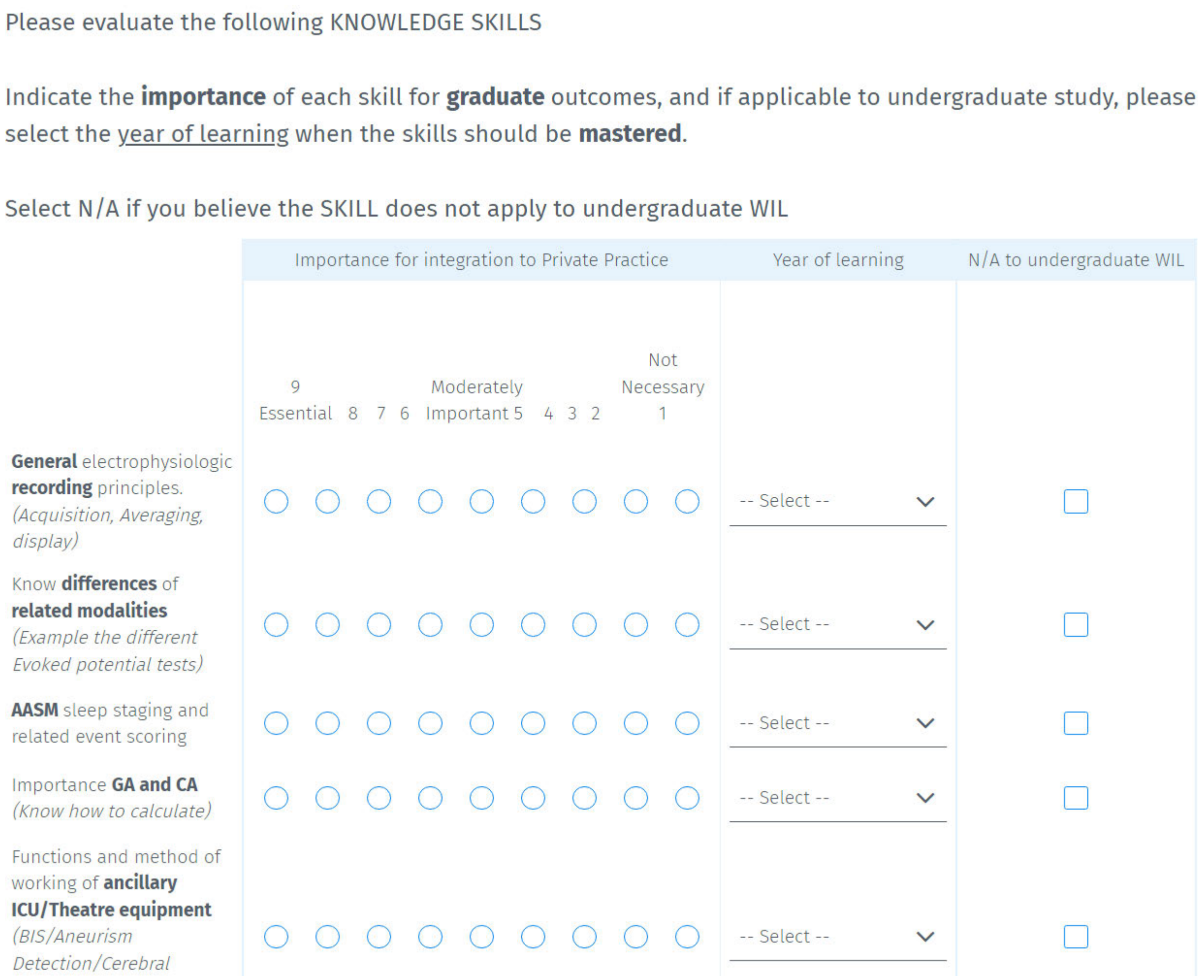
3.11.4.1.4 Practical and theoretical prerequisite skills

All skills and attribute contributions from Q1 were analysed and condensed into theme statements which in turn were included in previously defined function, duty, and task groups (Human 1996). These functions and related duties and tasks are summarised in Table 3.4.

Each group of practical skills statements were presented to participants in a tick-box style question where statements were listed as rows and modalities as columns (Figure 3.7). Participants were asked to indicate all modalities that each skill statement applies to. Participants could also indicate the N/A option if they believed the skill was inappropriate for the BHS WIL period. The aim here was to determine which skills are modality specific or have a general overarching relevance to CN WIL modalities.

Figure 3.7: Example of modality matching to skill statements

Similarly, the Q1 contributions on prerequisite theoretical knowledge were analysed and condensed into theme statements. All condensed theoretical knowledge statements were presented to participants in matrix-style question where statements were listed as rows (Figure 3.8). Columns included a nine-point Likert scale question and a dropdown selection of outcome year for achieving the knowledge outcome. Participants could also indicate the N/A option if they believed the theoretical knowledge outcome was inappropriate for the BHS WIL period. The aim was to determine the requisite theoretical knowledge pertaining to WIL that is required for successful graduation, and which year of study should target each knowledge statement.


Please evaluate the following KNOWLEDGE SKILLS

Indicate the **importance** of each skill for **graduate** outcomes, and if applicable to undergraduate study, please select the year of learning when the skills should be **mastered**.

Select N/A if you believe the SKILL does not apply to undergraduate WIL

	Importance for integration to Private Practice									Year of learning	N/A to undergraduate WIL
	9 Essential	8	7	6	Moderately Important 5	4	3	2	Not Necessary 1		
General electrophysiologic **recording** principles. *(Acquisition, Averaging, display)*	○	○	○	○	○	○	○	○	○	-- Select --	☐
Know **differences** of **related modalities** *(Example the different Evoked potential tests)*	○	○	○	○	○	○	○	○	○	-- Select --	☐
AASM sleep staging and related event scoring	○	○	○	○	○	○	○	○	○	-- Select --	☐
Importance **GA and CA** *(Know how to calculate)*	○	○	○	○	○	○	○	○	○	-- Select --	☐
Functions and method of working of **ancillary ICU/Theatre equipment** *(BIS/Aneurism Detection/Cerebral*	○	○	○	○	○	○	○	○	○	-- Select --	☐

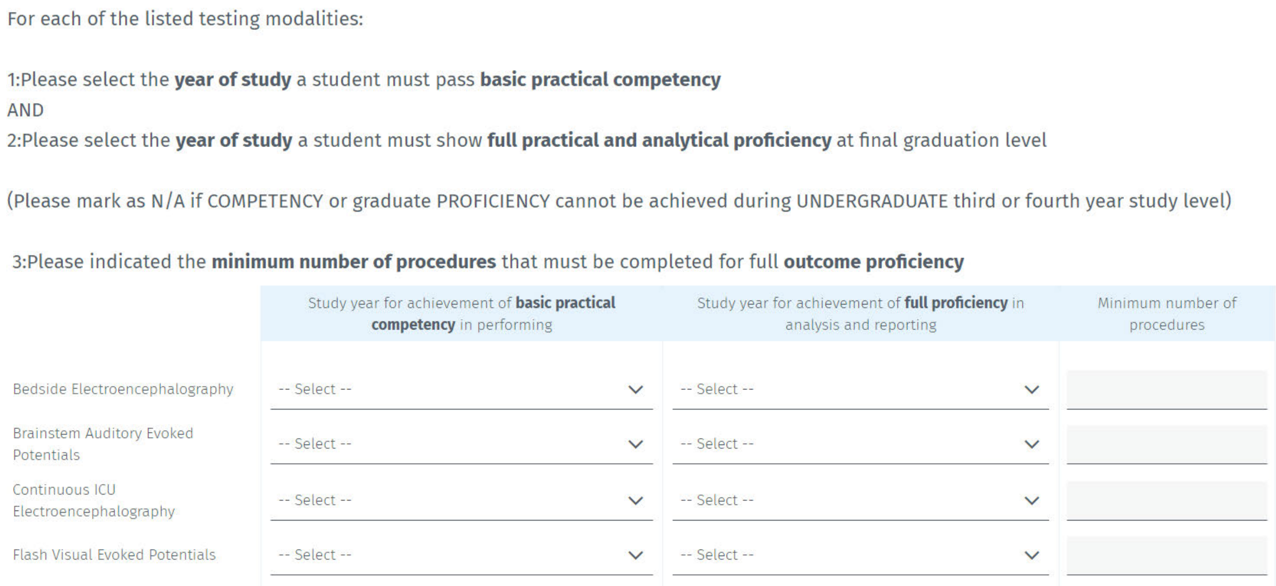
Figure 3.8: Example of theoretical skills importance and outcome rating question

3.11.4.1.5 Modality skills outcome year and minimum number of procedures

Earlier questions addressed the requisite graduate outcome level. However, in order to structure the WIL period, it was necessary to determine the appropriate outcome per year of learning for each modality.

Outcome levels were defined as either basic practical competency or full proficiency in analysis and reporting (Paragraph 3.13.1.2).

Participants were asked to indicate the appropriate OSL per year of study and minimum number of procedures for attaining full proficiency per test modality (Figure 3.9).



For each of the listed testing modalities:

1:Please select the **year of study** a student must pass **basic practical competency**
AND
2:Please select the **year of study** a student must show **full practical and analytical proficiency** at final graduation level

(Please mark as N/A if COMPETENCY or graduate PROFICIENCY cannot be achieved during UNDERGRADUATE third or fourth year study level)

3:Please indicated the **minimum number of procedures** that must be completed for full **outcome proficiency**

	Study year for achievement of **basic practical competency** in performing	Study year for achievement of **full proficiency** in analysis and reporting	Minimum number of procedures
Bedside Electroencephalography	-- Select --	-- Select --	
Brainstem Auditory Evoked Potentials	-- Select --	-- Select --	
Continuous ICU Electroencephalography	-- Select --	-- Select --	
Flash Visual Evoked Potentials	-- Select --	-- Select --	

Figure 3.9: Skills outcome level per year of study and minimum procedure numbers

3.11.5 Determining study endpoint

The possibility of a third questionnaire was entertained for the eventuality that the results of Q1 and Q2 were completely dichotomous, and no framework could be identified.

3.12 Definition of consensus

The purpose of a Delphi study can be finding existing consensus, facilitating consensus finding (building of consensus), or establishing the existence of a stable yet

diverse set of opinions referred to as a dissensus (Iqbal and Pipon-Young 2009; Marsh-Nation 2019). It is therefore possible to have a Delphi study with the aim of reporting the level of consensus found, rather than aiming at developing consensus. Iqbal and Pipon-Young (2009) stated that the first step towards designing a Delphi study is usually determining the aimed outcome (Iqbal and Pipon-Young 2009). Mullen (2003) and Holey *et al.* (2007) suggest that achieving stability in responses, rather than strict consensus may be more important, or useful, as this would be a true reflection of the state of knowledge. Determining the aimed outcome can influence the stopping point of a Delphi process. As the aim of this study was to explore and describe the requirements of a four-year BHS degree the researcher decided to use known measures of consensus to determine existing levels of agreement and set predetermined consensus threshold indicators to find the core neurophysiology modality related skills for the BHS degree.
The definition of consensus thresholds however proved to be poorly defined in literature.

Rohan, Ahern and Walsh (2009) also found that literature on the Delphi technique does not stipulate when consensus has been reached. They report arbitrarily selecting a mean score of $\geq$ 4.0 on a five-point Likert scale with a standard deviation of $\leq$ 1.0 as consensus. In 2018 Gallotta, Garza-Reyes and Anosike described consensus as a general agreement or majority opinion of a specific group. This they defined 75% or greater agreement with the average group response value to a given ordinal rank question. Consensus can however be described in various other ways (Diamond *et al.* 2014) and there is no standardised cut-off level of consensus as the subject and aim of the study will influence the level of agreement required (Gallotta, Garza-Reyes and Anosike 2018).

Diamond *et al*. (2014) performed a systemic Delphi review of 100 randomly sampled healthcare studies that used the Delphi method. The primary goal of their review was to determine previous definitions of consensus in healthcare Delphi studies. They also investigated whether the Delphi studies under review aimed at development of consensus, the endpoint of each study, and the stopping criteria used. Their review included whether the studies under review used a predefined measure of consensus.

In this current research several different variables, and relationships between variables, relating to WIL in CN were investigated and therefore appropriate consensus rules needed to be defined for each. The results of the methods review conducted by Diamond *et al*. (2014), was used as a foundation to look at consensus definitions from previous healthcare research and formulate a guide to finding appropriate measures for this study. Table 3.2 lists the consensus definitions found in other healthcare studies. The definitions from previous healthcare Delphi studies summarised in Table 3.2 were adapted from Diamond *et al*. (2014), von der Gracht (2012), Boulkedid *et al*. (2011), and Beiderbeck *et al*. (2021).

Table 3.2: Definitions of consensus from previous health care studies

	Definitions from previous Delphi studies	Example
1	Formal measure of agreement	Kappa, Cronbach's alpha, interclass correlation coefficient, Kendal's W
2	Rand criteria	No more than two ratings outside of a three-point range, including the median. Valid if rated as 7+ without disagreement.
3	Measure of central tendency	Mode, Median, Mena ranking used to indicate groups ranking. Mode: Not useful with scales with many values Median: Ranked data, not useful for scales with few values Mean: Can be used for un-skewed data, valid for ratio/interval data
4	Percent agreement	> 80% with the same rating (or other specified percentage)
5	Central tendency restricted to a specific range	Mean greater than seven on a nine-point scale
6	Central tendency within an unrestricted range	Median between seven and nine for appropriate, one and three for inappropriate, or four to six for equivocal with a range less than three
7	Proportion within a restricted range	90% (or other predefined percentage) scoring > 7 on and nine-point scale
8	Proportion within an unrestricted range	75% (other specified percentage) of participants rated 7, 8, 9 or 1, 2, 3.
9	Decrease in variance	Interquartile range less than three on a nine-point scale
10	Stability	< 15% change in distribution of responses (consensus or dissensus)
11	Rank	Rank order
12	Interquartile range (IQR)	Measure of dispersion for the median. Consensus is achieved If the middle 50% of observations range by less than the threshold. 4, 5, 7-point: < 1 9, or 10-point < 2
13	Tertial distribution	> 75% of ratings in either the lowest or highest tertial
14	Coefficient of variation (COV)	A consistent decrease in COV between rounds indicate increase in consensus; COV < 0.5 indicate reasonable internal agreement; good degree of consensus.
15	Average percent of majority opinion	3-point scales: Agree, disagree, N/A or cannot comment. Majority Agreements + Majority Disagreements divided by sum of comments provide cut-off percentage for consensus
16	Maximum difference of percentage of the scale	Threshold of a maximum of 25% of the respective scale (e.g., 25 on a scale from 0–100, or 1.25 on a scale from 1–5)

Birko, Dove and Ozdemir (2015) also described different levels of consensus measurements. They investigated the effect of number of questions and panel size on different measures of consensus. They calculated a dependency value ranging from

0.000 to 1.000 where 0.000 showed complete independence and a value of 1.000 complete dependence. They found that the number of questions did not have a noticeable effect on any of the agreement measures. One of the consensus measures that they investigated was described as "looking at the frequency of ratings falling within either the lower or upper extreme point ranges on a scale" (Birko, Dove and Ozdemir 2015: 3). This is equivalent to measure eight in Table 3.2 from the study by Diamond *et al.* (2014). Birko, Dove and Ozdemir (2015) found that on a dependency scale of 0-1 the maximum expected difference of this measure will be 0.021 or, when translated to a percentage scale, a difference of 2.1%.

Another review study looking at Delphi processes in healthcare research reported using a tertial distribution of ratings in either the lowest or highest tertial (Boulkedid *et al*. 2011) This is similar to the "central tendency" within a restricted or unrestricted range methods described by Diamond *et al*. (2014) and summarised in Table 3.2 as methods five, six, and eight.

For the aim and objective of this study it was necessary to use multiple measures of consensus to accommodate various question types across the two different questionnaires. These included selection frequency importance ranking, Likert scale ordinal data, and weighted rank order questions. Different question types were used to differentiate between essential modalities, prerequisite and dependent modalities and skills, and outcome skills level relationship to year of learning and minimum clinical exposure for outcome attainment.

In this study it was decided to keep a recurrent 75% threshold as standard across all measures and any single selection with a greater than 75% majority was considered consensus irrespective of additional measures. In rank order questions a tertial distribution for restricted ranges was used in addition to visual Pareto analysis.

3.13 Data analysis of online questionnaires

Data analysis was accomplished using available statistical tools from the QP online analysis desktop. Further offline data processing was conducted using Microsoft® Office 356® Excel® (Excel). A detailed descriptive analysis was accomplished using pie-graphs, Pareto charts, histograms, and tables. Sample demographic data from both Q1 and Q2 were analysed for proportional representation.

3.13.1 Analysis of quantitative data and determining consensus in Q1

Descriptive statistics were used in the analysis of Q1 skills outcome selection questions. Analysis of nominal and rating data aimed to reveal existing consensus regarding core CN testing modalities and OSL per modality upon WIL completion. The median, mean, standard deviation of the mean (SD), standard error of the mean (SE), 95% confidence interval for the mean (CI), and a coefficient of variation (COV) were calculated for all skills outcome rating questions. The proportional percentage agreement (PA) with the mean and the median score was calculated for comparison to the selection modal score selection frequency. Work on Delphi consensus by Hsu and Sandford (2007) found that in most instances where central tendency was measured the median, rather than the mean, was indicative of the collective judgements of participants. Von der Gracht (2012) reiterated the use of the median rather than the mean for ordinal data. The median indicates the aggerate group response, while the standard deviation shows the level of disagreement (Holey *et al.* 2007).Both were examined for completeness. The mean and median were calculated to investigate the influence of outliers in identifying level of consensus according to the percentage of agreement calculation (Gallotta, Garza-Reyes and Anosike 2018). A decrease in SD and COV between rounds was used to track increase or decrease in agreement.

3.13.1.1 Percentage agreement to the mean and median rating

Percentage agreement was calculated by dividing the mean and median response value by the maximum response value of the rating scale.
Skills rating questions in this research used a 5-point rating scale as follows:

1 = Perform recording
2 = Analyse results
3 = Technical report (description of findings)
4 = Interpretative report (identification of abnormal findings)
5 = Clinical diagnostic report (providing a clinical diagnosis)

For this, and other Likert agreement scale questions, the calculated non-rounded mean, rounded mean, and median selection value, and the PA to these values were calculated following the formula described by Gallotta, Garza-Reyes and Anosike (2018):

$$Average = \frac{\sum_{0}^{n} response\ value}{n}$$

n = the maximum scale value (5 for a five-point scale, or 9 for a nine-point scale etc.).

$$Percentage = \frac{Average}{5}$$

$Average$ = the first calculated value, or statistical mean, and n = the maximum scale value (5 for a five-point scale, or 7 for a seven-point scale etc.).

Similarly, the PA to the non-rounded mean (PANRM) and median were calculated (Hsu and Sandford 2007).

An acceptance score of at least 75% was considered evidence of consensus. All majority selections were presented back during Q2 for controlled feedback, possible consensus building through reconsideration of personal selection, and response stability testing (Habibi, Sarafrazi and Izadyar 2014).

The rank order importance of modalities was determined through selection frequency and selection power calculations.

Pearson's correlation coefficient was used to evaluate the selection frequency effect of additional votes from participants that cast more than ten votes in the multi-voting question in Q1. Table 3.3 summarises guidelines for the interpretation of correlation coefficient values adapted from Hinkle, Wiersma and Jurs (2003).

Table 3.3: Guideline for interpretation of Pearson correlation coefficient size

Size of Correlation	Interpretation
.90 to 1.00 (−.90 to −1.00)	Very high positive (negative) correlation
.70 to .90 (−.70 to −.90)	High positive (negative) correlation
.50 to .70 (−.50 to −.70)	Moderate positive (negative) correlation
.30 to .50 (−.30 to −.50)	Low positive (negative) correlation
.00 to .30 (.00 to −.30)	negligible correlation

3.13.1.2 Consensus in Q1

The first step was to determine core or essential modalities to include in the WIL period. Consensus regarding essential, or core, modalities was sought using the nominal group technique of multi-voting. A rounded down version of the "one-half plus one votes per person" non-weighted multi-voting method was used to find priority ranking through group opinion for all testing modalities (Schenkelberg 2021). Each participant was given ten votes to cast against the modalities they viewed as essential outcome modalities to reveal the aggregate group order of importance according to the number of participants that selected the testing modality.

- A first-round negative consensus was applied where any modalities with > 75% exclusion from selection (less than 25% frequency of representation) were excluded from further skills investigation.

The results of the multi-voting were reviewed for consensus versus dissensus according to percentage selection frequency. Using multi-voting can streamline the process of finding the highest priority or most supported ideas and consensus in multi-voting where participants can cast multiple votes to one idea has been described as items receiving twice as many votes as the number of voters (Schenkelberg 2021). In this research study each participant was able to cast one vote per modality for a maximum of ten modalities and therefore negative consensus was applied when less than 75% of participants cast any vote to a modality. It was decided that if a strong dissensus was displayed whereby this criterion could not be implemented, all modalities that obtained any votes would be carried to the second round for weighted ranking.

Therefore, consensus was defined using rank order representation according to participant selection frequency. Consensus regarding exclusion of the least important testing modalities was sought. If $\geq$ 75% of participants did not consider the modality essential for inclusion, it was excluded from the Q2. Each modality carried to Q2 therefore needed proportional agreement of $\geq$ 25% of participants as an essential modality.

It must be noted that participants were not instructed to choose fundamental modalities, but rather outcome modalities, which could lead to more advanced modalities receiving more votes than some prerequisite modalities. Hypothetically it was theorised that “neonatal EEG” may receive more votes as an essential outcome modality rather than “routine EEG”, however routine EEG would need to be mastered first. Some participants did select advanced modalities such as SE LTEM and SG LTEM without selecting the presumed prerequisite routine EEG modality. This presumption was tested in Q2.

- The second type of consensus measuring used in Q1 was the mean and median selection score and PA to the mean and median scores.
- This was calculated together with the confidence interval and coefficient of variation and reported in Table 4.5.

This was used for the graduate level outcome skills levels per modality. Each modality was scored on a Likert scale rating the OSL from lowest to highest rating for that particular skill on predefined outcomes. The majority category selection was compared to the mean and median selection rating for equivalence and the group agreement percentage was calculated to determine consensus to the mean and median selection. Where no single score received a $\geq$ 75% modal selection, the agreement with the mean and median score was used to define the level of existing consensus.

3.13.2 Analysis of qualitative data from Q1

Open-ended text comments detailing the embedded prerequisite practical skills, knowledge skills, personal skills (graduate attributes), and theoretical knowledge required to master each modality were analysed manually for replicating skills elements or themes. A combined list of all contributions per testing modality was downloaded from QP and organised into Excel® spreadsheets. Keywords were identified during reading and keyword searches for skills elements were completed across all sheets. A separate sheet was used to group recurrent statements and skill elements. A separate sheet was used to categorise condensed statements into theme categories.

All text statements were read, interrogated repeatedly, themes identified, and related themes condensed. Final statements were contextualised and grouped into thematic categories according to the KT functions, duties and tasks defined by the 1994 clinical technology workgroup (Human 1996) (see Section 3.11.4.1.4).

Furthermore, the SAVKT referred to “personal attributes” of a KT (SAVKT 1986; Human 1996). Little detail was given, and broad statements only included the ability to work with the ill, attention to neatness, detail and accuracy, an aptitude for mathematics, science, and electronic apparatus. Human (1996) further noted attributes such as communication, dedication, teamwork, and honesty. Table 3.4 contains a summary of these KT and KTG functions and related tasks. Each duty action key word was also related to several requisite tasks.

Table 3.4: Clinical technologists' functions and related tasks and activities

Duty Function	Tasks
Perform	Clinical evaluation and selection of modality, patient and equipment preparation. Recording and evaluation of physiological signals etc.
Analyse	Analysis of examination. Observation of results with clinical correlation and integration through comparison to normative data. Evaluation, and reporting of results etc.
Communicate:	Patient orientation. Communication with colleagues, administration and management, teamwork and negotiation, verbal and written reporting, training and patient history taking etc.
Control quality	Equipment maintenance with knowledge of equipment setup and upgrading. Implementation of standardised procedures with evaluation of quality and safety procedures etc.
Management	Leadership and personnel management. Motivate, advise, and promote staff development. Planning of procedures and delegation of tasks. Record keeping, statistical reporting. Stock control and budgeting etc.
Train	Student work integrated learning (WIL), advice and assistance, and evaluation. Structured continuing education and medical ethics. Consultation with healthcare management organisations.
Research	Development of a research topic, literature review, protocol development, data gathering, analysis and reporting.

3.13.3 Analysis of quantitative data and determining consensus in Q2

The same data analysis methods were used for Q2 as described for Q1. In addition, weighted rank, tertial, and Pareto analysis were applied during reporting.

Questionnaire 2 aimed to address differentiation between foundational and core required outcome modalities. All modalities that passed the $\geq$ 25% proportional agreement for inclusion from Q1 were included in Q2.

Analysis was performed for inter-related learning dependency, outcome skills level, the importance of embedded practical and theoretical knowledge and abilities, as well as outcome year for either basic competency or advanced proficiency in each modality.

3.13.3.1 Consensus in Q2

- Three questions addressed clarification of agreement from Q1. Binary majority agreement was used for evaluation of these questions.

Question 18 in Q2 asked participants to rank all 16 modalities in order of importance.

- Weighted rank order analysis was performed to finalise essential modalities for inclusion in a four-year undergraduate BHS in CN. A weighted rank scale of 1 through 16, where 1 represents the highest importance, was used.
  - Tertial distribution (Boulkedid *et al*. 2011) was used to identify consensus regarding lowest importance. Modalities rating in the third quartile (less than the 25th percentile of the scale) were considered non-essential for inclusion in the four-year BHS.
  - Modalities that did not achieve a weighted average rank of more than 4.75 were considered not to reach the minimum consensus for inclusion in an undergraduate degree (Table 3.5).

Table 3.5: Quartile values of a 16-point weighted rank order scale

Quartile	Value	Definition
Q1	4.75	Lower 25th Percentile
Q3	12.25	Upper 75th Percentile
Q4	16	100% Agreement
Interquartile range	16	4.75-12.25

Questions 20 through 35 of Q2 explored the interdependence of essential modalities for facilitating learning during WIL.

- Modalities were presented in a randomised order and each participant was asked to categorise modalities as either dependent on prior knowledge of the modality under investigation, or as a prerequisite to learning of the modality being investigated (see Figure 3.4, Section 3.11.4.1.2, page 75).

The frequency of participant selection rate was calculated. Selection frequencies were used to identify modalities inter-related for learning as either a prerequisite for learning, or dependent on prior knowledge of all other modalities.

Participant selection frequency was calculated to determine percentage representation of the inter-modality relationship before rank order for importance could be assessed. For example, if a modality received only a single selection in either category the importance rank would be 1. However, the participant selection frequency would be 0.3% illustrating the non-related relationship.

For modality framework development it was important to determine prerequisites and dependencies of all modalities in consideration of all other modalities. It was also important to determine the degree of prerequisite importance or dependency. Relative importance of each modality was measured against the rest. This lent ranking weight to frequency of choice in determining position in the undergraduate WIL framework.

Skills and knowledge questions were scored on a nine-point Likert scale. Skills statements were evaluated for their modality relationship and knowledge statements were assessed for importance for the qualification as a whole. General graduate attributes were assessed for importance as outcome attributes for the BHS, and according to year of learning.

- A 75% selection frequency proportion within a restricted range of 7-9 was used to determine consensus on essential relationships (Table 3.2 definition 8).

Rounded mean selection was used for classifying modality basic competency or advance proficiency and general skills and attribute outcomes as either a third or fourth year of study aim.

3.13.3.2 Definition of outcome skills level descriptor terms

The word "competency" was used to describe the ability to practically perform a test modality and obtain quality results. These results are used for analysis and reporting toward accurate diagnosis and treatment. Competency is the first learning assessment outcome tested during the first year of WIL training. This assessment is also referred to as a CBT.

The word "proficiency" is used to describe the ability to analyse, report, interpret and correlate results with clinical information toward obtaining a clinically relevant result. Accurate diagnosis and treatment are based on this report. Proficiency is the second and the highest learning outcome assessed at the end of the WIL period. This assessment is referred to as a proficiency assessment.

The desired outcome level for a four-year undergraduate degree was investigated in Q1. Questionnaire 2 was used to test for robustness in participant agreement and to determine which outcome level should be attained at the end of the third and the fourth year of study. The results of both questionnaires are reported in Chapter 4.

3.13.3.3 The Pareto principle

There are certain instances where the average rank importance does not translate well into directing effective learning.

- Hypothetical example: Modality A only received three selections in relationship to modality B. Two of these selections were as a prerequisite and one was as a dependent modality. Using participant selection frequency, the modality relationship selection frequency was 9% (n = 3 selections of n = 32 participants) in total, with a 6% selection frequency as a prerequisite and only 3% selection frequency as dependent. Using a selection ratio of 2:1 per category would have skewed the results with Modality A appearing to have a 66% prerequisite value and therefore high importance for learning Modality B. The average rank scores would be misleadingly high, as the low frequency selection of a dependent modality would indicate a mean rank of 1, or 100% dependency, while the selection frequency indicates a trivial level of relationship between these modalities.

All modalities with a selection frequency relationship of more than 25% were evaluated for degree of dependency/pre-requirement for learning using Pareto analysis. Graphical display of the inter-related relationships was accomplished using Pareto charts. A Pareto chart shows the cumulative importance of items under investigation (Clinical Excellence Commission 2021), plotting all observation items as a bar graph in descending order. It may also have a “Pareto line” which is a cumulative percentage line that indicates each successive item’s observation contribution to the total number of observations, or the combined power of those observations (Pyzdek and DeFeo 2021; qimacros.com 2023). Charts may also have a percentage cut-off line, frequently at 80% (Figure 3.10) (Clinical Excellence Commission 2015; Institute for Healthcare Improvement 2017).

Pyzdek and DeFeo (2021) refer to the items as the "trivial many", however instead of using a strict cumulative percentage contribution cut-off they look at the slope of the Pareto line and identify obvious breaks in the slope as illustrated in Figure 3.11. From this it is clear that the essential few vs useful many do not always strictly fit within the rigorous theoretical 80:20 division. The cumulative percentage line of the Pareto chart was used to display these relationships graphically. The 80% point intersects with the 75th percentile of the 0-1 rank scale (Figure 3.10). This is said to separate the ''vital few'' from the ''useful many'' (Best and Neuhauser 2006; Kenton 2022).

This study investigated all modalities that passed Q2 criteria as essential outcome modalities for related modalities and used the selection frequency representation of each modality to determine the cumulative percentage contribution to learning and measured the cumulative effect these have. In the event where there were less clear break zones for visually determining the essential few. The researcher considered differentiating between essential, useful, and trivial according to the tertial distribution. All modalities in the third quartile (above the 75th percentile) were categorised as the essential few, modalities in the interquartile range were categorised as useful, and modalities with less than 25th percentile representation were classified as of trivial importance for learning of non-related modalities.

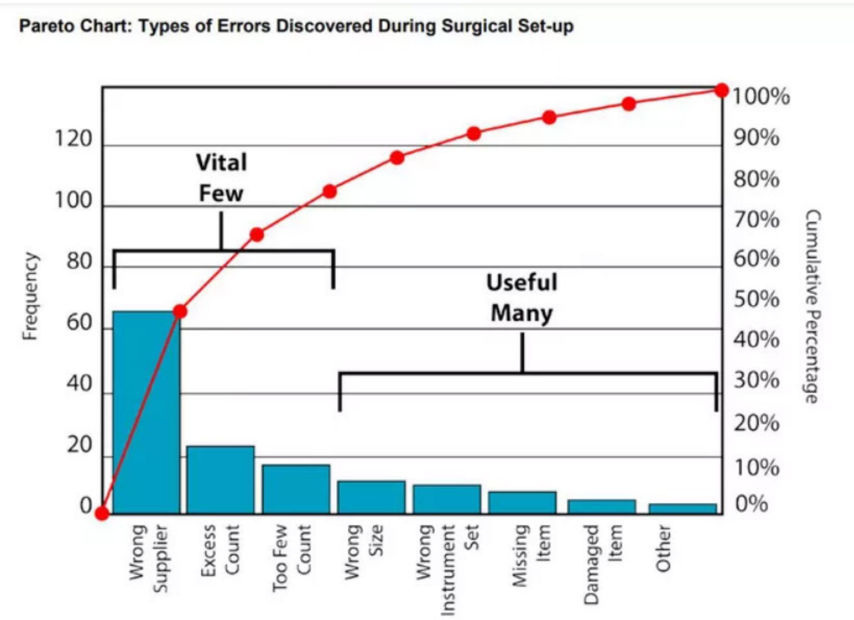


Figure 3.10: Example of Pareto analysis using the 80:20 principle
Source: Kenton (2022)

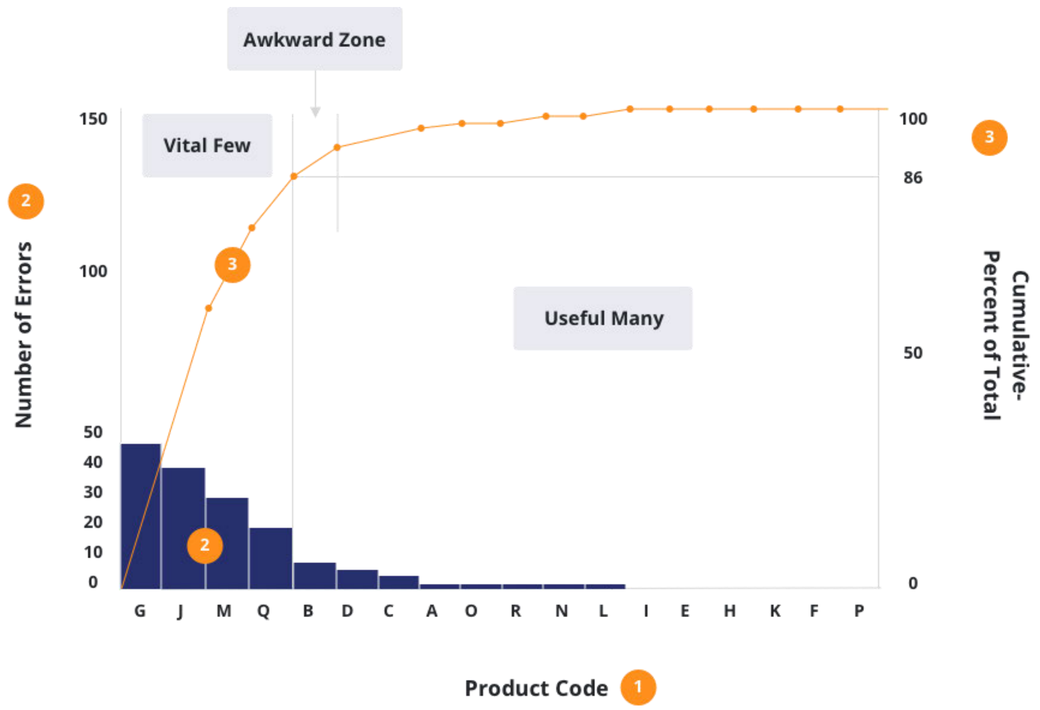


Figure 3.11: Pareto chart interpretation using break zones
Source: Pyzdek and DeFeo (2021)

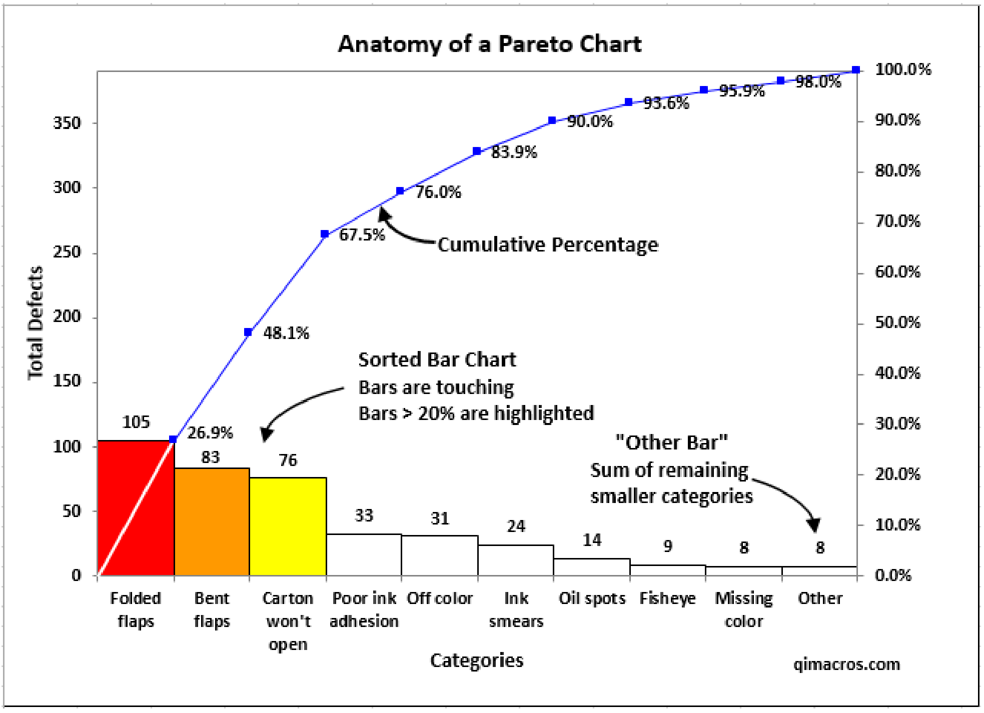


Figure 3.12: Anatomy of a Pareto chart
Source: qimacros.com (2022)

3.14 Results comparison between Q1 and Q2

Response stability and convergence towards consensus were tested for skills outcome selections. Decreasing COV below 0.5 was used as an indication of convergence towards consensus. A < 15% change in PA to the mean and median score was seen as stability of opinions.

3.15 Framework development

Quality control tools were used for diagrammatic framework development (Kent 2016). The essential outcome modalities and related embedded skills were processed according to outcome year. Initially affinity diagrams were used, and modalities were sorted according to outcome year. Related dependent or prerequisite modalities and related embedded skills were combined into third- and fourth-year tree or driver diagrams for competency and proficiency outcome skills.

3.15.1 Year of learning

The first step toward framework development was to differentiate between year of learning.

All modalities that passed the inclusion threshold in Q2 were evaluated for outcome year for either basic competency or advanced proficiency. Where both outcomes were in the same year outcomes where further grouped into basic or advanced per year.

Next all other practical skills, knowledge skills, and graduate attributes were sorted for outcome year. These were then assessed for modality relationships and the framework developed around essential outcome modalities.

3.15.2 Modality relationships

Modality relationships were investigated to find the modality with the highest number of dependent modalities. Modalities were paired or grouped with dependent modalities into an “affinity diagram” (Clinical Excellence Commission 2021). Initially multiple affinity diagrams were used for basic competency and advanced proficiency per outcome year.

All third-year basic competency and advanced proficiency outcome modalities were identified. In each group the diagram started with the modality with the largest number of dependencies, these dependencies were listed in order of decreasing dependence rank where clear importance rank could be identified. Each of these were then investigated for their dependencies. This process was repeated until each modality had a list of dependent modalities in order of importance.

In these affinity diagrams the first modality became the category heading and was referred to as the primary driver. The modalities under each heading became our secondary drivers (Clinical Excellence Commission 2021).

In this way it is possible to see which modalities drive learning of subsequent modalities and find the most efficient learning pathway (Kent 2016). This process was repeated until a logical pattern emerged, and all modalities were incorporated.

3.15.2.1 Relationship diagrams

Affinity diagrams (Figure 3.13) (Goldenratio 2009) were used to sort prerequisite or dependent modalities into related categories of dependency or prerequisite relationships (Clinical Excellence Commission 2021). The top level was the attainment of the BHS. The second level was named according to each outcome year, the next level consisted of the prerequisite outcome modalities, which in turn was followed by dependent and prerequisite modalities. Once the affinity diagrams were in place tree or driver diagrams incorporating embedded skills and attributes were developed.

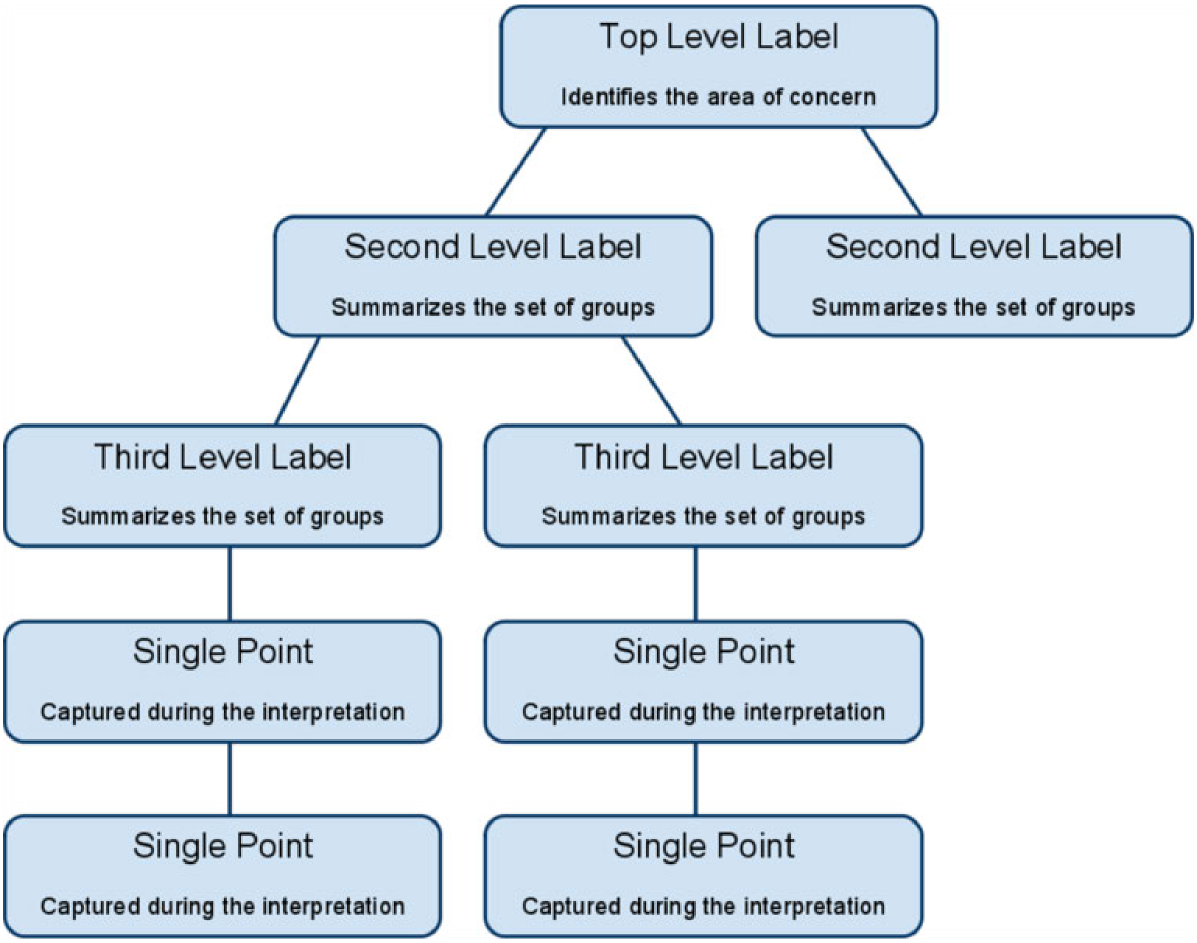


Figure 3.13: Example of an affinity diagram
Source: Goldenratio (2009)

Figure 3.14 and Figure 3.15 demonstrate different ways in which driver diagrams can be used to illustrate how the related skills and graduate attributes contribute to prerequisite modalities which in turn drive learning toward outcome modalities and outcome year.

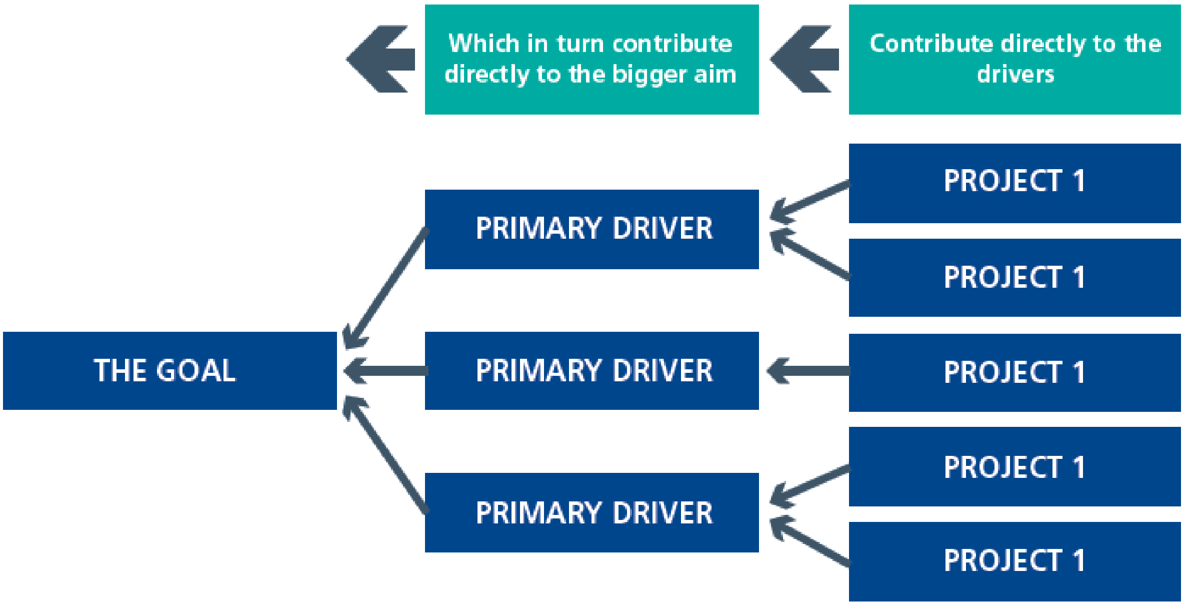


Figure 3.14: Example of a driver diagram
Source: Clinical Excellence Commission (2021)

2020 Developmental Screening Quality Improvement Project

AIM	Drivers	Tests of Change
By December 31, 2020, 69% of sites listed in REDCap will be conducting developmental screening.	Local public health department provides education and promotion of developmental screening in their community	• Include information in birth letters to families • Provide trainings to specified target audience (physicians, child care providers, community partners) • Intentional outreach to target audiences via email, call and in-person meetings • Share information at a community event
	Collaborate with relevant partners	• Attend early childhood coalition meetings • Provide technical assistance to partners • Share best practices with or across Health Departments • Develop relationships with a clinical partner who is conducting developmental screening
	Promote screening availability by multiple partners in the community	• Explore who in the community is currently using screening • Provide screening opportunities at established events
	Advocate for systems that identify children in need of screening or appropriate follow-up	• Share data with partners to create common messaging • Work with statewide organizations including WPHA, WCHQ, WNA, WHA and WI AAP to discuss advocacy efforts • Identify a community champion to support advocacy efforts
	Conduct a community assessment	• Identify where screening is being done in your community • Identify what resources are available and what resources are needed • Identify who is interested in receiving training
	Promote established referral networks	• Provide information to partners on Regional Centers for Children and Youth with Special Health Care Needs • Provide information to partners on Well Badger • Maintain local listing of resources
	Participate in learning community opportunities on developmental screening	• Initiate discussions with other health departments • Share resources and best practices • Document your Plan-Do-Study-Act (PDSA) cycles • Participate on learning community calls • Partner with the Medical Home Initiative for technical assistance

Figure 3.15: Example of a driver diagram in quality improvement
Source: Children's Health Alliance of Wisconsin (2020)

3.15.3 Embedded skills and graduate attributes

Once modalities driving learning per year were identified the embedded skills and attributes could also be investigated for outcome year and modality relationships.

Once all modalities were incorporated, the affinity diagrams were converted to driver diagrams (Clinical Excellence Commission 2021). This was accomplished in a stepwise fashion. The first modality was listed as the first primary driver and all dependent modalities were listed as secondary drivers. Subsequent affinity groups were added as tertiary drivers to the secondary drivers in sequential order. Skills and attributes were assigned to the modality with the highest relationship in the first position in the framework.

3.16 Conclusion

This Delphi study consisted of three rounds of data gathering and processing.

The first round used purposeful sampling of known pioneers in both CT education and the development of CN in South Africa, current CN WIL providers, and a thorough literature review of published and unpublished sources. Unpublished documents included available course syllabi, documents of the first professional society founding members, and other documents received from CT and CN professional or educational pioneers. Unstructured interviews with these individuals introduced snowball sampling whereby the researcher was directed to additional sources of personal communication not originally known to the researcher.

Using the information from both the personal communications and literature the first electronic survey instrument was formulated, Q1. This questionnaire consisted of both open and closed-ended questions and was used as the instrument for a second round of data gathering.

Questionnaire 1 yielded the insights of private practice CNPs on outcome needs and supplied the researcher with a broad base of qualitative data from which to extract the knowledge and expertise of participants.

Descriptive statistics were used to quantify data during analysis and the results of the Q1 analysis were formulated into a second quantitative electronic survey instrument, Questionnaire 2, which was used as the data gathering instrument for the third and final round of data gathering.

Participation in answering Q2 was open to all qualified CNPs in South Africa. Questionnaire 2 presented participants with collated data from Q1 and tested for consensus on core CN modalities, graduate skill outcome levels, and the learning relationships and dependencies between core modalities. General graduate personal attributes, or soft skills, and embedded practical skills were also investigated.

The results after three rounds of data gathering and processing were used to answer the research questions as set out in Table 1.1 and Table 1.2. A teaching and learning framework was developed for the CN WIL period using the modality interrelated learning dependencies of core modalities and cross modality embedded skills.

Analysis and results are presented in Chapter 4 and discussed in Chapter 5. The teaching and learning framework is presented as the conclusion of the research in Chapter 6.

CHAPTER 4: RESULTS

This chapter provides a report on the results from Q1 and Q2 and, where appropriate, a consensus comparison. The combined results are discussed in Chapter 5 and were used to formulate a proposed WIL learning content framework for CN in South Africa.

4.1 Sample statistics for Q1

4.1.1 Completion rate

Initially 179 email invitations were sent out. A total of 62 potential participants accessed the link and consented to participate. A total of 51 participants fulfilled the inclusion criteria of which 50 participants contributed to the initial essential modality selections and 28 completed all questions. One participant only completed the demographic questions. The completion rate was 56% of participants who initially accessed the questionnaire.

Seventy-six per cent of participants were female and 24% were male.

4.1.2 Post qualification experience

After initial launch of Q1 the researcher had to adjust the wording of the post-qualification experience demographic question (Figure 4.1).

Figure 4.1: Q1 Post-qualification experience demographic question

The initial phrasing of “Public (State) Practice Only” was found to be unclear and two participants requested new participation links. The phrasing was adjusted to “Public

Service (State/Government) Practice Only". A total of three consenting participants were excluded from contributing further to Q1 according to this choice. As two participants requested new links a single potentially qualifying participant was excluded. This ambiguity therefore had minimal effect on the completion rate.

Of the 51 initial participants 51% reported post-qualification experience limited to private practice, while 49% reported experience in both private and public/government service. This near equal split is illustrated in Figure 4.2.

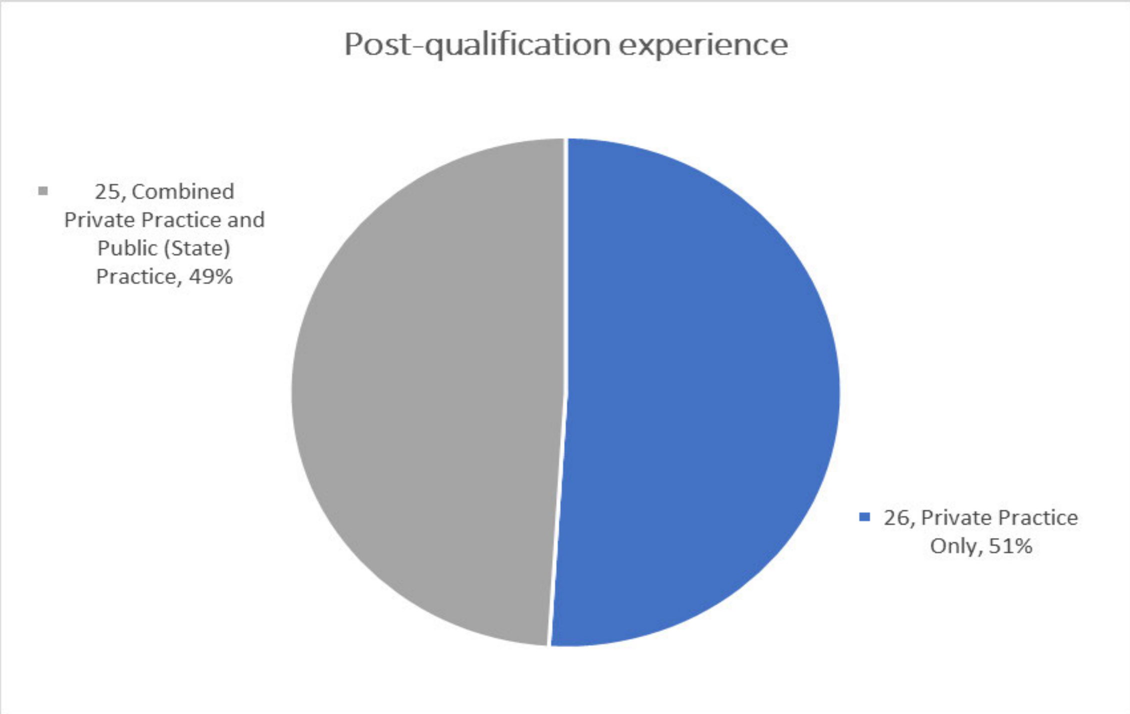


Figure 4.2: Q1 participants' post-qualification experience

4.1.3 HPCSA registration status

Of the 51 HPCSA registered CNPs that participated in Q1 only three indicated registration as supervised practice (6%). The division between private practice and independent practice registration was near equal at 45% (n = 23) private practice and 49% (n = 25) independent practice registration. This distribution is illustrated in Figure 4.3.

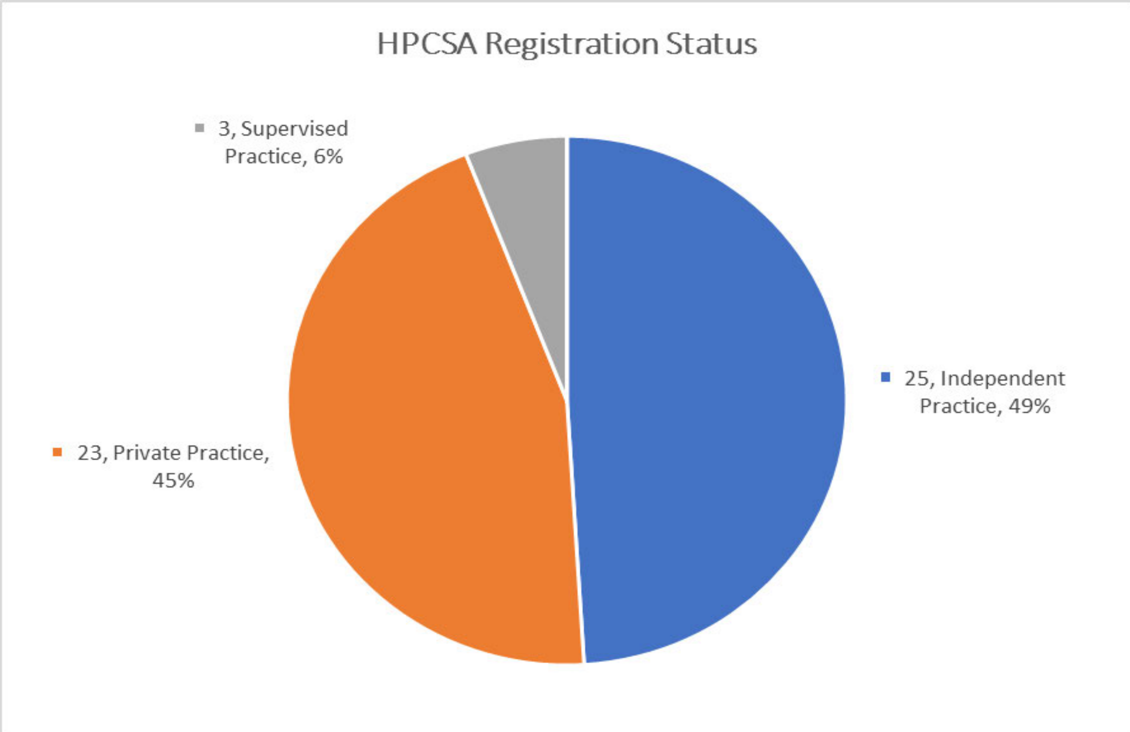


Figure 4.3: Q 1 participants' HPCSA registration status

4.1.4 Highest qualification

The percentage distribution of highest CT qualification of Q1 participants is illustrated in Figure 4.4.

Most participants had B Tech qualifications (n = 42; 82%). Three participants reported a higher qualification (n = 3; 6%), two reported having a BHS (n = 2; 4%), and one selected the "other option" as a Bachelor of Science degree (BSc) in physiology (n = 1; 2%). Three participants (n = 3; 6%) reported having N Dip qualifications. Of these two, one indicated a pre-2001 and one a post-2001 N Dip qualification. This is important as a pre-2001 N Dip is an independent practice qualification, whereas a post-2001 qualification will be a supervised practice qualification if there is no completion of a B Tech degree.

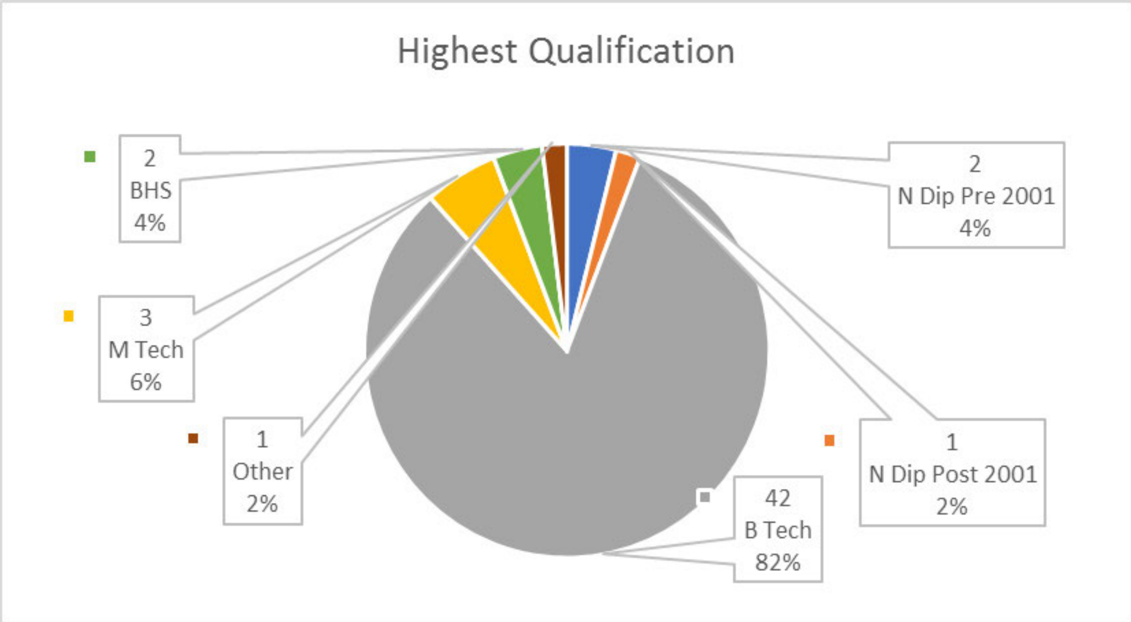


Figure 4.4: Highest qualification of Q1 participants
Abbreviations: BHS – Bachelor of Health Science; N Dip – National Diploma; M Tech – Master of Technology; B Tech – Bachelor of Technology.

4.2 Modality selection ranking according to participants' selections

The results of modality importance ranking contribute to answering the first aim and research question as set out in Table 1.1 and Table 1.2.

In Q1 participants were presented with the 24 CN test modalities (listed in Table 2.5). During analysis, EMG and assist with EMG were combined as one test modality with "assist with" as an outcome practice skill level.

Participants were asked to use their expert opinion to select the 10 most essential modalities for private practice integration upon graduation in a multi-voting question. Using proportional representation all test modalities that were selected by less than 25% of participants were identified as non-essential for inclusion in the four-year BHS degree WIL programme. Only essential modalities were included in Q2.

Fifty of the 51 participants (n = 50) contributed to essential modality selections and subsequent questions. A total of nine participants (n = 9) selected more than the requested 10 modalities and 41 participants selected 10 or fewer (n = 41). Subgroup analysis was conducted between the n = 50 group and the n = 41 subgroup that selected 10 or less modalities. This was done to determine whether including the selections from participants that selected more than 10 modalities had any significance on the outcome of the total group selection results. A non-significant effect would indicate robustness of group selection regardless of the number of modalities participants selected.

Table 4.1 reports the comparison of participant modality selection frequency and selection power between the n = 50 and n = 41 participant groups. Graphic representation of modality selection for these two groups are shown in Figure 4.5 and Figure 4.6. Figure 4.7 includes a representation of the n = 9 group that cast more than 10 votes.

The only difference in modality selections between the n = 41 and n = 50 groups was the inclusion of the modality flash visual evoked potentials (FVEP). Of participants in the n = 50 group, 26% included FVEP in their essential list. Twenty-two per cent of the n = 41 group selected FVEP. FVEP was therefore considered a non-consensus test modality that needed to be re-assessed in Q2.

Drug administration (Drugs) and TCD were both selected by 24% of participants in the n = 50 group and this representation decreased to 22% in the n = 41 group. Both modalities were excluded from the essential core modality list. A total of 15 of the original modalities qualified for further analysis. Only one modality, non-invasive positive airway pressure therapy (NIV PAP), was added by a single participant to the original list of modalities compiled from historic South African training documents (Table 2.5).

The only difference in category separated modality selection was the absence of maintenance of wakefulness testing (MWT) and memory testing (MT) in the n = 41 group. When response selections were added from the participants that selected > 10 skills, these modalities received only three and two selections respectively, but still did not reach the inclusion threshold. Interdependent relationship for TLA of individual modalities within each of these categories were further tested in Q2.

Table 4.1: Modality selection results from Q1

	Modalities	n=50	Participant Frequency	Power	n=41	Participant Frequency	Power	Percentage difference	
		Votes	%	%	Votes	%	%	Power	Frequency
1	BAEP	32	64%	6%	24	59%	6%	0,2%	5%
2	Bedside EEG	35	70%	7%	28	68%	7%	-0,2%	2%
3	cICU EEG	26	52%	5%	20	49%	5%	0,0%	3%
4	CBM	3	6%	1%	2	5%	0%	0,1%	1%
5	DBS	6	12%	1%	4	10%	1%	0,2%	2%
6	Drugs	12	24%	2%	9	22%	2%	0,1%	2%
7	FVEP	13	26%	2%	9	22%	2%	0,3%	4%
8	IONM	19	38%	4%	15	37%	4%	-0,1%	1%
9	SG LTEM	16	32%	3%	12	29%	3%	0,1%	3%
10	SE LTEM	27	54%	5%	22	54%	5%	-0,3%	0%
11	MWT	3	6%	1%	0	0%	0%	0,6%	6%
12	MT	2	4%	0%	1	2%	0%	0,1%	2%
13	MSLT	36	72%	7%	27	66%	7%	0,2%	6%
14	EMG	38	76%	7%	30	73%	7%	-0,2%	3%
15	Neonatal EEG	43	86%	8%	34	83%	8%	-0,2%	3%
16	NCS	50	100%	10%	41	100%	10%	-0,6%	0%
17	PRVEP	24	48%	5%	17	41%	4%	0,4%	7%
18	PNUS	2	4%	0%	1	2%	0%	0,1%	2%
19	PSG	48	96%	9%	39	95%	10%	-0,5%	1%
20	Routine EEG	45	90%	9%	36	88%	9%	-0,3%	2%
21	SSEP	31	62%	6%	24	59%	6%	0,0%	3%
22	TCD	12	24%	2%	9	22%	2%	0,1%	2%
23	WADA	0	0%	0%	0	0%	0%	0,0%	0%
24	NIV PAP	1	2%	0%	1	2%	0%	-0,1%	0%
		524		100%	405		100%		
		n = 50			n=41				

Abbreviations for Figures 4.1-4.7 and Tables 4.1-4.4: BAEP – brainstem auditory evoked potential; EEG – electroencephalogram; CBM – cortical brain mapping; cICU EEG – continuous ICU EEG; DBS – deep brain stimulation; Drugs – drug administration and management of adverse effects; FVEP – flash visual evoked potential; IOM – intraoperative monitoring; IONM – intraoperative neuromonitoring; LTM – long-term monitoring; LTEM – long-term EEG monitoring SG LTEM – LTEM with subdural grid electrodes; SE LTEM – LTEM using surface electrodes only; MWT – Maintenance of Wakefulness Test; MT – memory testing; MSLT – multiple sleep latency test; EMG – electromyography; NCS – nerve conduction studies; PNUS – peripheral nerve ultrasound; SSEP – somatosensory evoked potential; TCD transcranial Doppler; WADA – WADA test; NIV PAP – non-invasive ventilation positive airway pressure; US – ultrasound

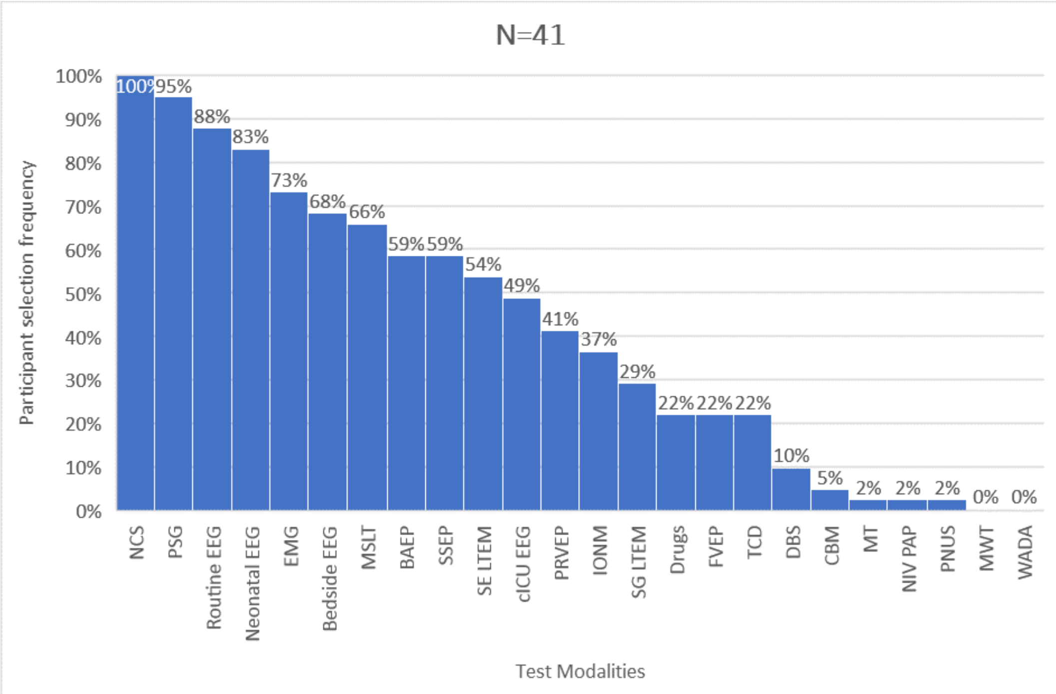


Figure 4.5: Frequency of modality selection for the n = 41 group

Figure 4.5 shows the Pareto graph representation of the n = 41 participant group's modality selection frequency in decreasing order of importance for inclusion in an undergraduate degree.

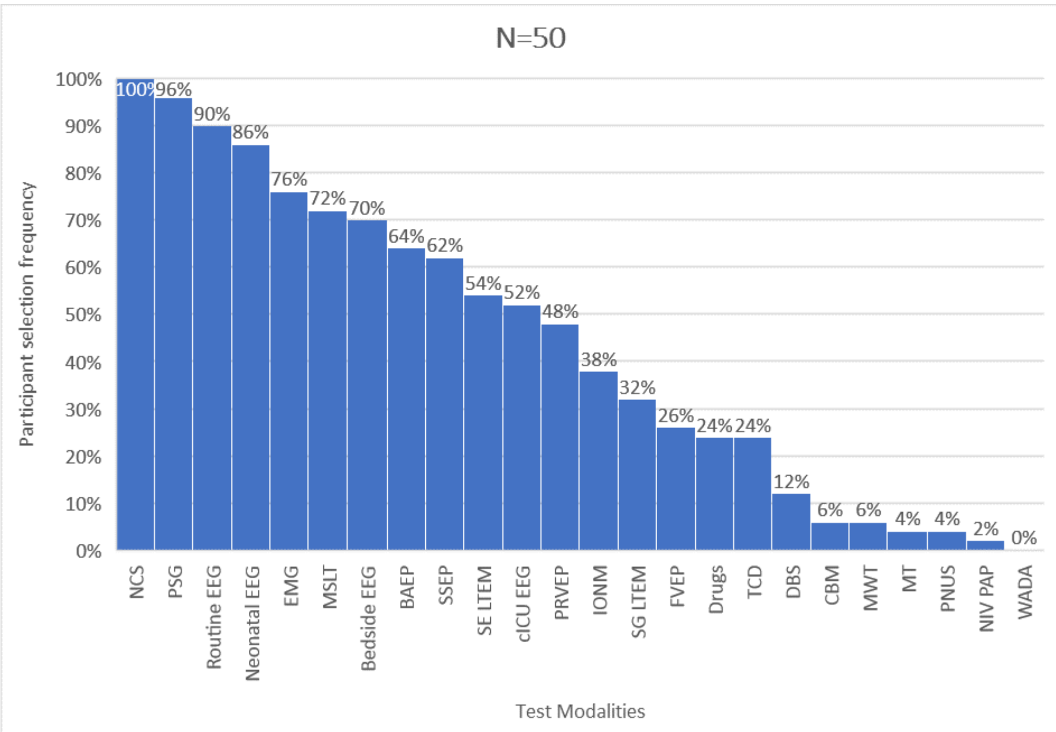


Figure 4.6: Frequency of modality selection for the n = 50 group

Figure 4.6 shows the Pareto graph representation of the n = 50 participant group's modality selection frequency in decreasing order of importance for inclusion in an undergraduate degree. Figure 4.7 shows the comparison between the n = 41 group and the n = 50 group

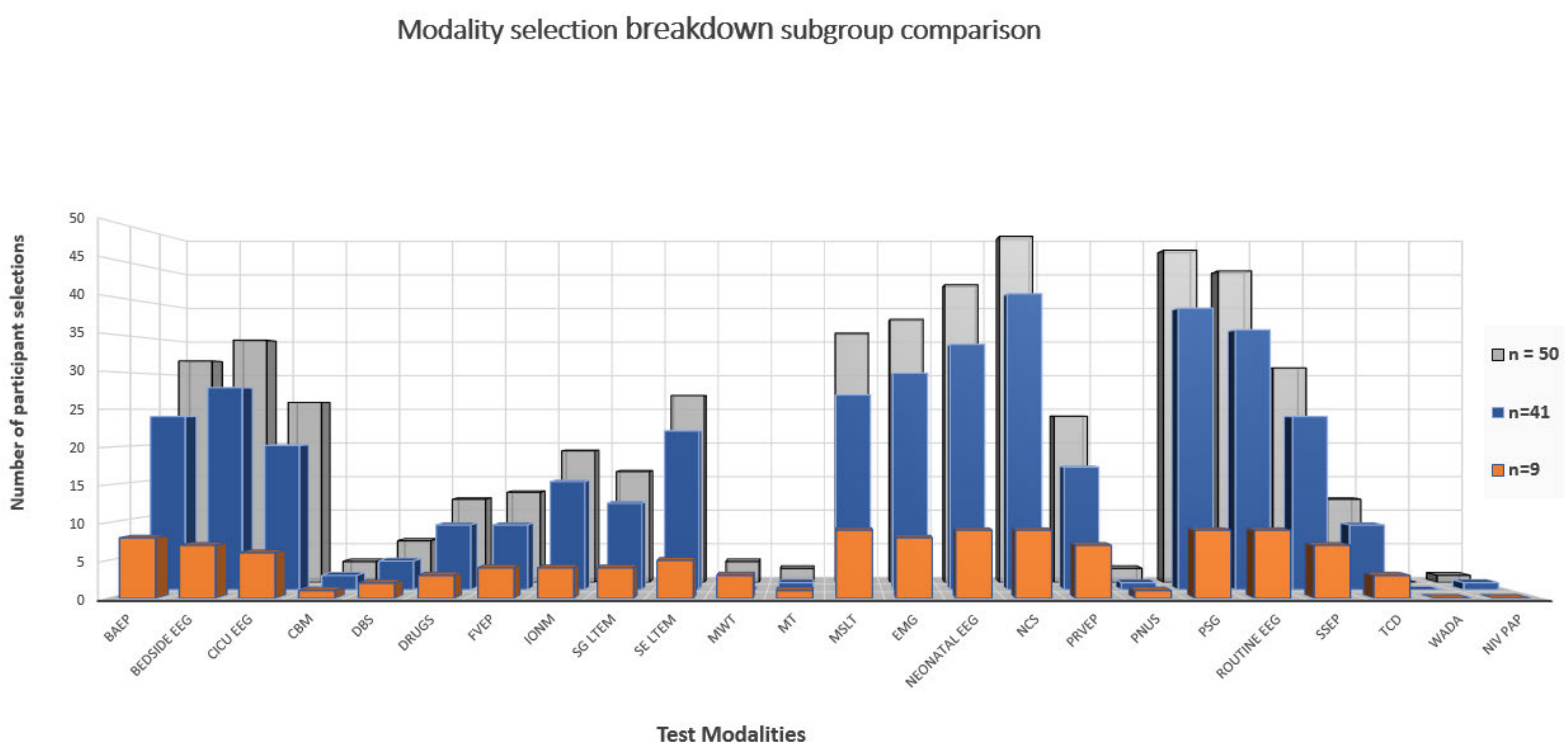


Figure 4.7: Modality selection group comparison n = 50, n = 41, n = 9

Histogram comparison of modality selection in the total n = 50 group with comparison to selection frequency of the n = 41 and n = 9 sub-groups.

4.3 Group correlation testing

Pearson's correlation testing was performed for both the power and frequency of selection of the n = 50 and n = 41 results. This was done to test the effect of the additional votes cast by the n = 9 group on the outcome of the total n = 50 results. The Pearson correlation coefficient for the participants' modality selection frequency was 0,998 and the correlation coefficient for the participants' selection power was 0,998. A correlation coefficient approaching 1 indicates that the additional voting power of the n = 9 group had minimal effect on group aggregate results and did not cause any skewing in modality inclusion for Q2 when using the n = 50 results (Table 3.3).

Results from the total n = 50 group was used for further analysis and identification of final essential modalities and are reported in Table 4.2 and illustrated in Figure 4.8. Table 4.2 and Figure 4.8 present the final 16 modalities selected as essential for inclusion in an undergraduate WIL programme.

Table 4.2: Q1 final essential modalities

	Modality n=50	Votes	Participant Frequency
1	NIV PAP	1	2%
2	FVEP	13	26%
3	SG LTEM	16	32%
4	IONM	19	38%
5	PRVEP	24	48%
6	cICU EEG	26	52%
7	SE LTEM	27	54%
8	SSEP	31	62%
9	BAEP	32	64%
10	Bedside EEG	35	70%
11	MSLT	36	72%
12	EMG	38	76%
13	Neonatal EEG	43	86%
14	Routine EEG	45	90%
15	PSG	48	96%
16	NCS	50	100%
		48	n=50

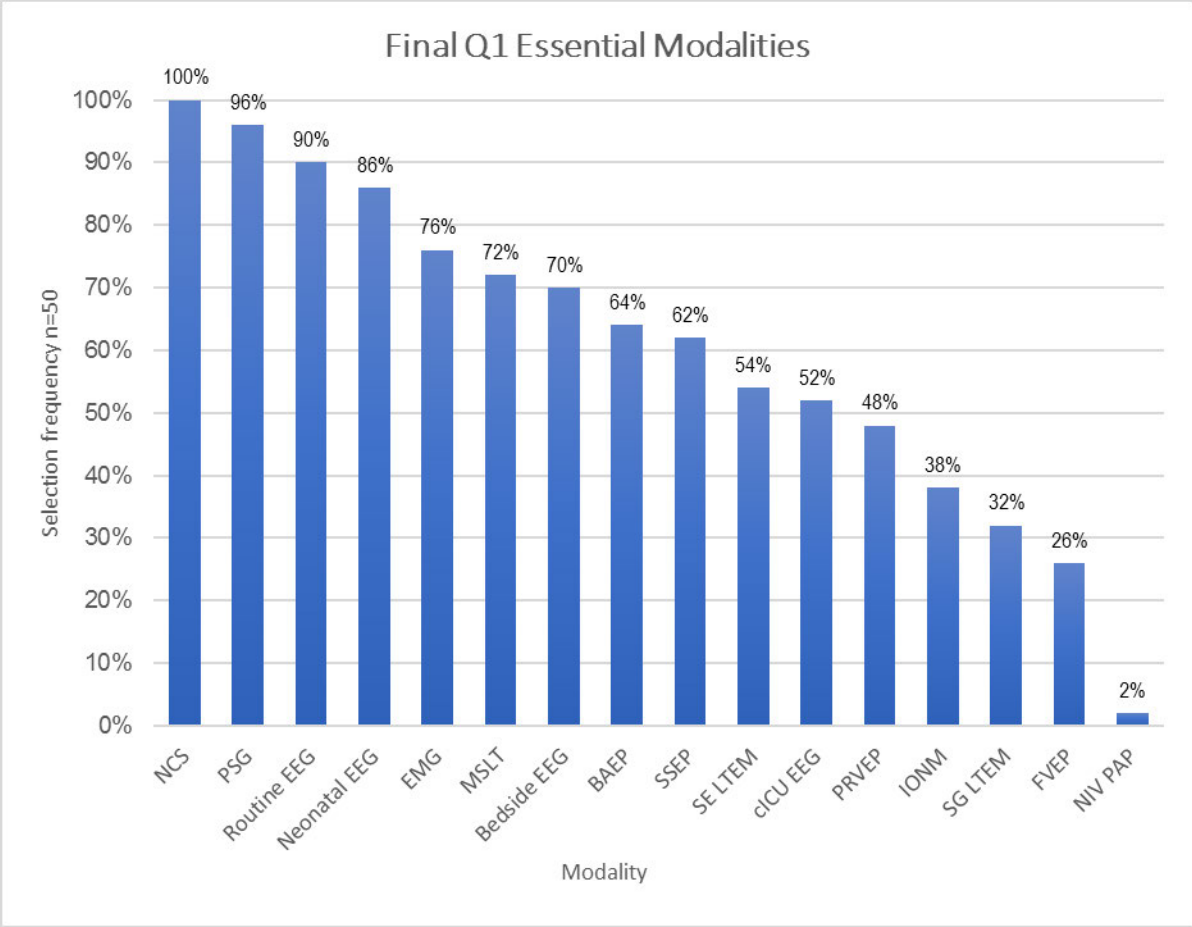


Figure 4.8: Q1 final essential modalities

4.4 Grouped modality ranking

Investigation of how individual modalities can be grouped as being related speaks to objective two and research questions two and three (Table 1.1 and Table 1.2).

To investigate interdependent importance relationships for TLA between individual modalities the test modalities were grouped into the eight previously defined categories of related modalities (Table 2.5).

Each of the modality categories previously identified were reviewed individually for frequency of participant selection and selection rate. Test modalities within each category were then tabulated and listed in order of decreasing selection frequency (Table 4.3). This order was used as an indication of decreasing importance for inclusion in undergraduate BHS WIL training.

A total of six grouped modality categories remained as essential using the < 25% group selection rate as cut-off criteria. The grouped importance ranking is displayed separately in Table 4.4.

Table 4.3: Grouped modality importance ranking within modality categories n = 50

EEG			EP			EMG/NCS			Sleep			LTM			IOM			Other			US		
	Count	%		Count	%		Count	%		Count	%		Count	%		Count	%		Count	%		Count	%
Routine EEG	45	37	BAEP	32	32	NCS	50	57	PSG	48	55	SE LTEM	27	39	IONM	19	68	Drugs	12	86	TCD	12	86
Neonatal EEG	43	35	SSEP	31	31	EMG	38	43	MSLT	36	41	cICU EEG	26	38	DBS	6	21	MT	2	14	PNUS	2	14
Bedside EEG	35	28	PRVEP	24	24				NIV PAP	1	1	SG LTEM	16	23	CBM	3	11	WADA	0	0			
			FVEP	13	13				MWT	3	3												
Total	123		Total	100		Total	88		Total	88		Total	69		Total	28		Total	14		Total	14	

Table 4.4: Modality categories with importance ranking of Q1 essential modalities

EEG			EP			EMG/NCS			Sleep			LTM			IOM		
	Count	%		Count	%		Count	%		Count	%		Count	%		Count	%
Routine EEG	45	37	BAEP	32	32	NCS	50	57	PSG	48	55	SE LTEM	27	39	IONM	19	100
Neonatal EEG	43	35	SSEP	31	31	EMG	38	43	MSLT	36	41	cICU EEG	26	38			
Bedside EEG	35	28	PRVEP	24	24				NIV PAP	1	1	SG LTEM	16	23			
			FVEP	13	13												
Total	123		Total	100		Total	88		Total	85		Total	69		Total	19	

In Table 4.3 and Table 4.4 modality categories are displayed left to right in order of greatest selection frequency. Modalities within each category are listed in order of decreasing selection importance from top to bottom. Collectively the six modalities remaining as core essential modalities in Table 4.4 received 484 votes out of a total of 524 votes (92%). All modalities in the US and Other category groups from Table 4.3 were rejected and the only IOM modality that was retained was IONM.

4.5 Essential modality analysis in Q1

The first aim and research question required determination of the core, or essential, clinical testing modalities (Table 1.1 and Table 1.2). This information was applied to answer research questions two and three and address the second and third aims and objectives.

Participants contributed their expert opinions regarding the required outcome skill level (OSL), theoretical skills, practical skills, and graduate attributes required for mastering each of their selected modalities.

4.5.1 Outcome skill level selections

Outcome skill level options were presented on a five-point Likert-type scale rated from competency in recording up to complete proficiency in reporting with clinical correlation as described in Section 3.13.1.1.
Exceptions to this were EMG and IONM scales where more outcome levels were needed. These will be described together with their respective results.

Determining consensus on minimum outcome practice skill levels addresses aim and objective three of the study (Table 1.1).

Three participants selected the ‘Other’ option and listed one or more of the scale options. This was attributed to the order randomisation of the question choices after reading participant comments. As the participation window was still open this randomisation function was removed from the electronic questionnaire with no further complex answers to this section of questions. This text data was incorporated as the most appropriate single choice during data clean-up.

One participant included practical or theoretical skills in their “other” free text field. These were manually added to the appropriate text comment section for thematic analysis.

The selection non-rounded mean, rounded mean, and median selection were calculated and related to the closest skills level. Results of this analysis is summarised for all modalities in Table 4.5.

4.5.1.1 EEG modality selections

All three EEG modalities were selected as essential, and routine EEG was indicated as the most important modality in the group through greatest selection frequency (Figure 4.9). Grouped EEG modalities received a total of 123 votes out of a combined 484 votes (25%). Routine EEG received only two more votes (n = 45, 37%) than neonatal EEG (n = 43, 35%) and only ten more than bedside EEG (n = 35, 28%).

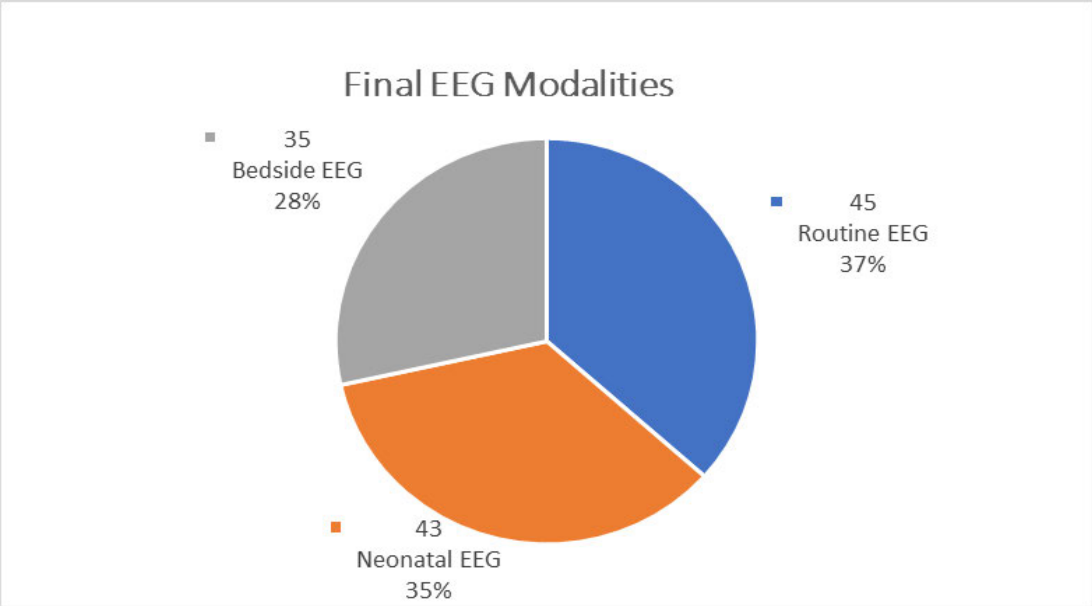


Figure 4.9: Final EEG modality selection frequency

4.5.1.1.1 Outcome skill levels for EEG modalities

Routine EEG, neonatal EEG, and bedside EEG all had a rounded mean score and median scores of 4.

- The modal OSL selection for routine EEG (Figure 4.10) was interpretative reporting. The percentage agreement with the non-rounded mean score (PANRM) was 73%, which was under the 75% agreement threshold for consensus. The PA with the rounded mean and median rating was 80% (Table 4.5), which satisfied the threshold for OSL consensus.
- The modal OSL selection of neonatal EEG (Figure 4.11) was interpretative reporting. The OSL PANRM was 75% (Table 4.5).
- The modal OSL selection for bedside EEG (Figure 4.12) was interpretative reporting. The PANRM was 78% (Table 4.5).

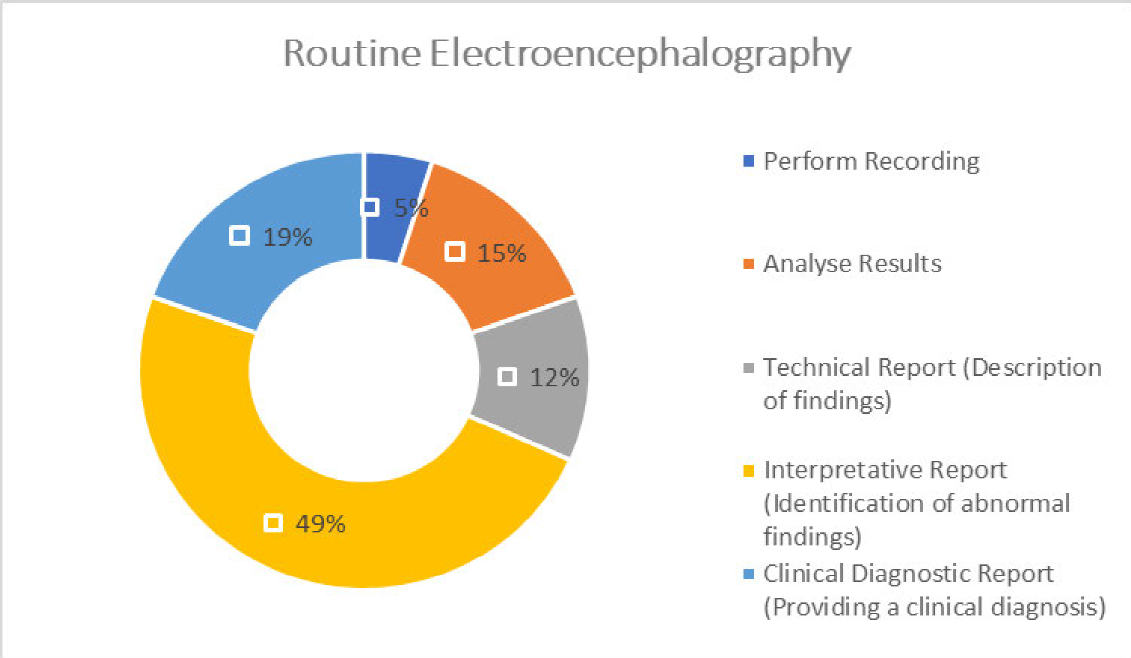


Figure 4.10: Routine EEG outcome skill level

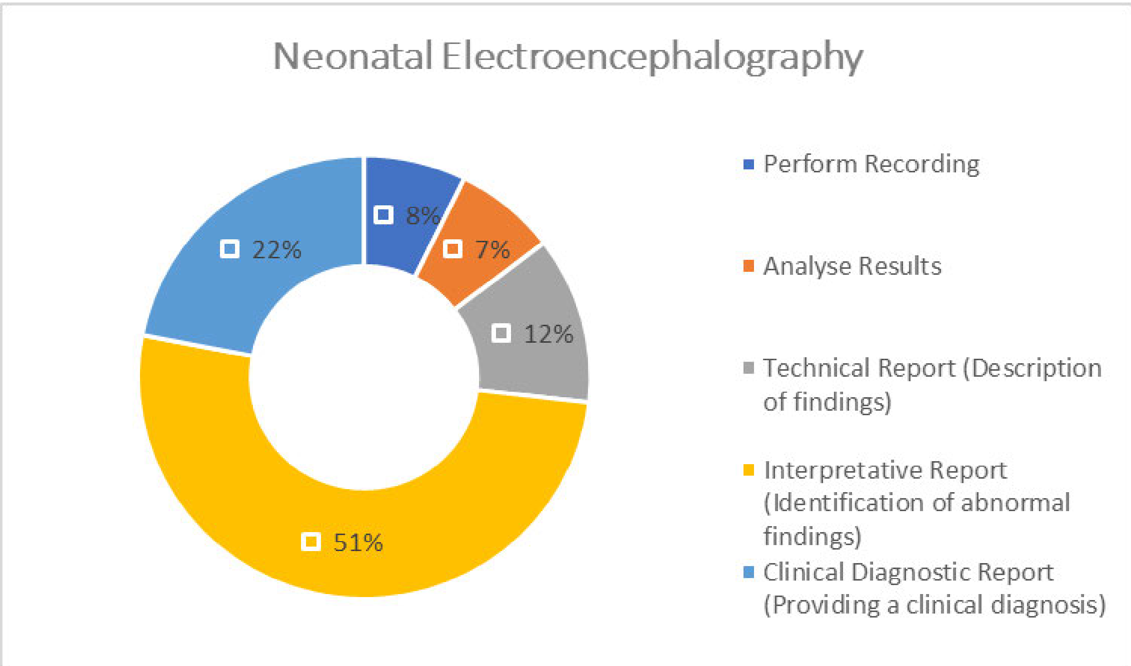


Figure 4.11: Neonatal EEG outcome skill level

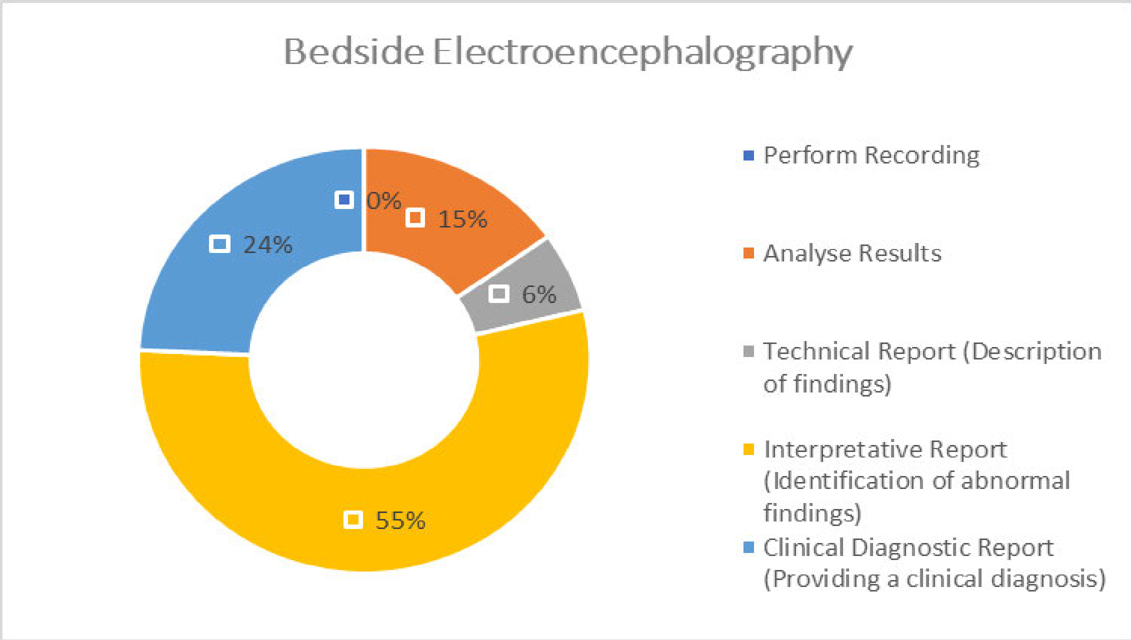


Figure 4.12: Bedside EEG outcome skill level

4.5.1.2 Evoked potential modality selections

All four original EP modalities were included for further analysis. Brainstem auditory evoked potential and SSEP scored nearly equal in importance (Figure 4.13). Grouped EP modalities received a total of 100 votes out of a combined 484 votes (21%). Brainstem auditory evoked potential and SSEP received 32% (n = 32) and 31% (n = 31) votes respectively. Pattern reversal visual evoked potential was lower at 24% votes (n = 24) and FVEP received 13% (n = 13) of the EP votes from a total of 26% of the 50 voting participants.

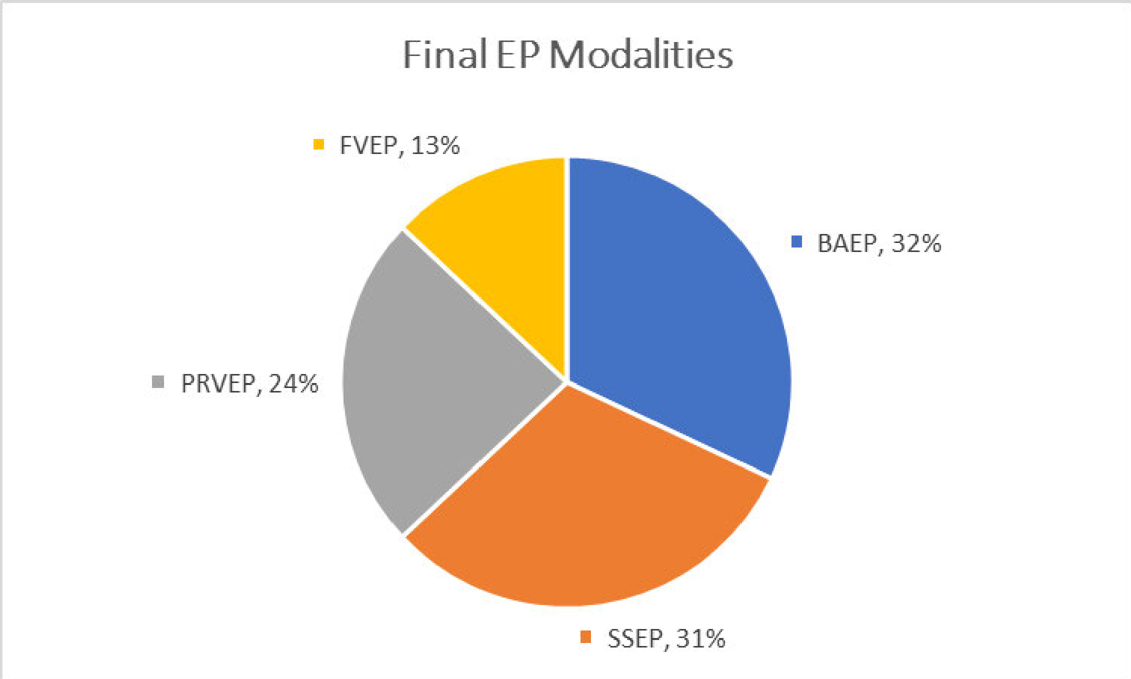


Figure 4.13: Final EP modality selection frequency

4.5.1.2.1 Outcome skill levels for evoked potential modalities

Brainstem auditory evoked potential, SSEP, and PRVEP all had a rounded mean score and median score of 4.

Flash visual evoked potential: The mean rounded score was 3, however the median score was higher at 3.5 indicating a split between technical and interpretive reporting.

- The modal OSL selection for BAEP (Figure 4.14) was interpretative reporting. The PANRM was 72%. The PA with the rounded mean and median rating was 80% (Table 4.5).
- The modal OSL selection for SSEP (Figure 4.15) was interpretative reporting. The PANRM was 72%. The PA with the rounded mean and median rating was 80% (Table 4.5).
- The modal OSL selection for PRVEP (Figure 4.16) was interpretative reporting. The PANRM was 72%. The PA with the rounded mean and median rating was 80% (Table 4.5).
- Modal OSL selection was equally divided between interpretative and clinical reporting for FVEP (Figure 4.17). The PANRM was 68%, and the median rating

was 70%, these were both under the 75% agreement threshold for consensus (Table 4.5).

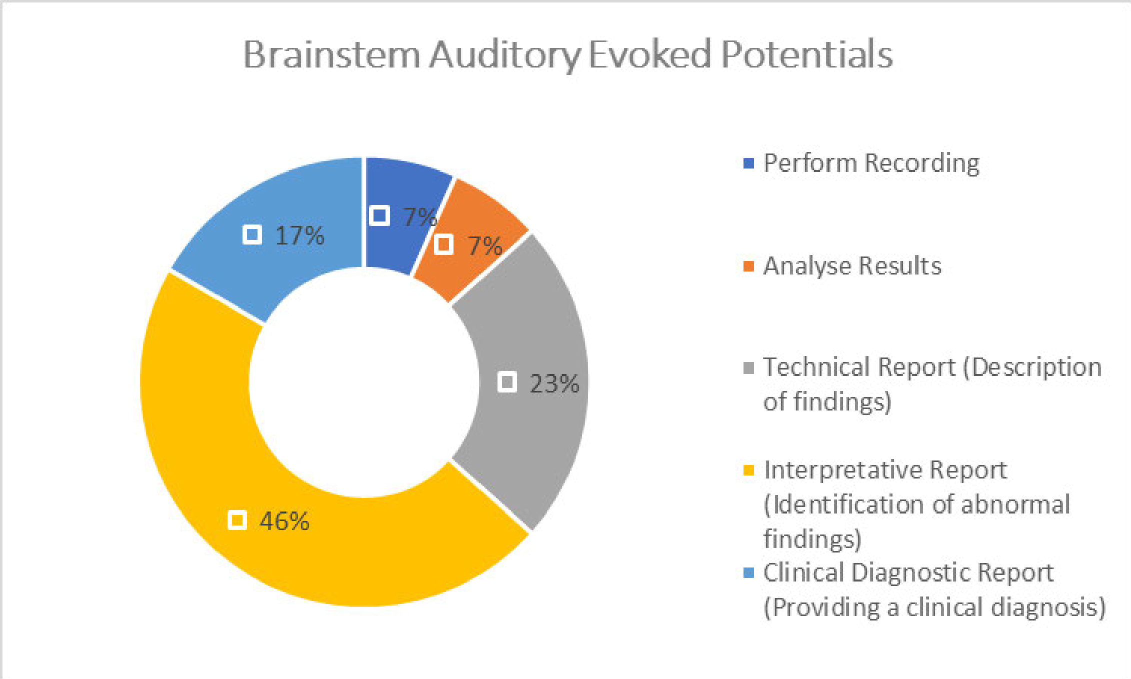


Figure 4.14: BAEP outcome skill level

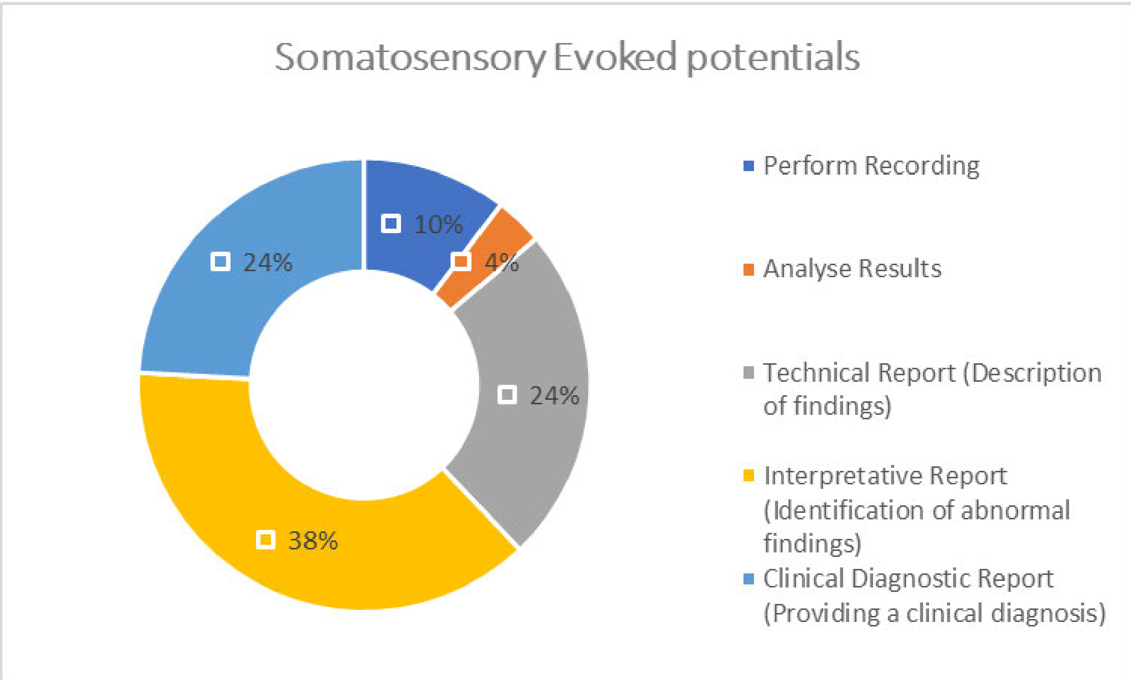


Figure 4.15: SSEP outcome skill level

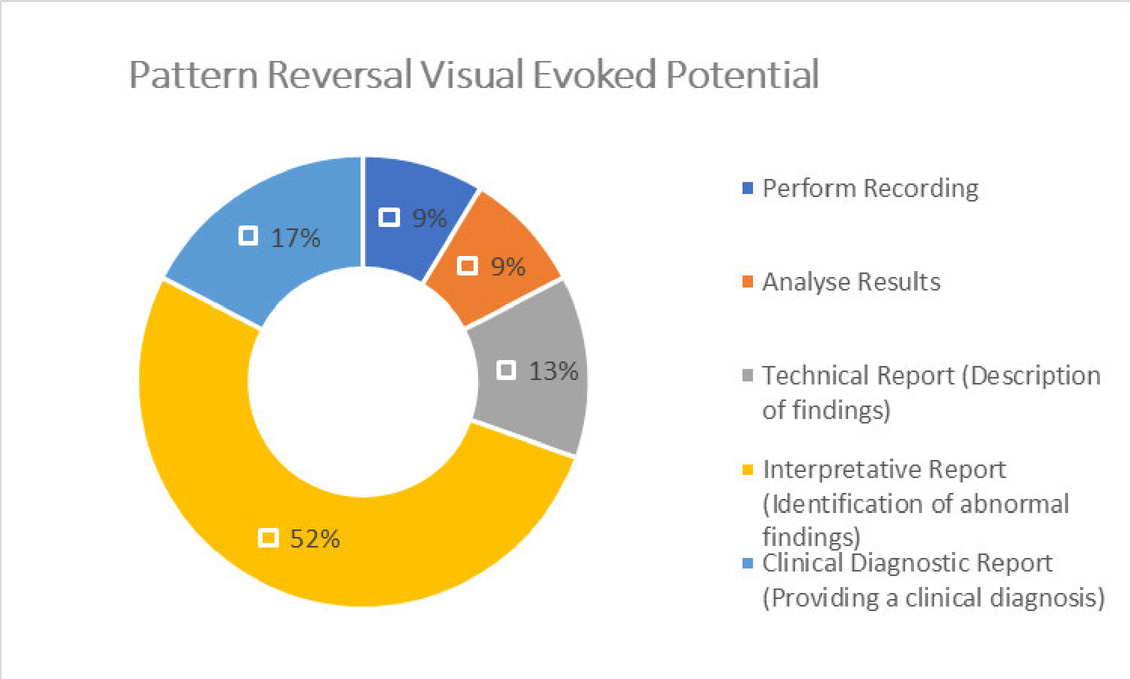


Figure 4.16: PRVEP outcome skill level

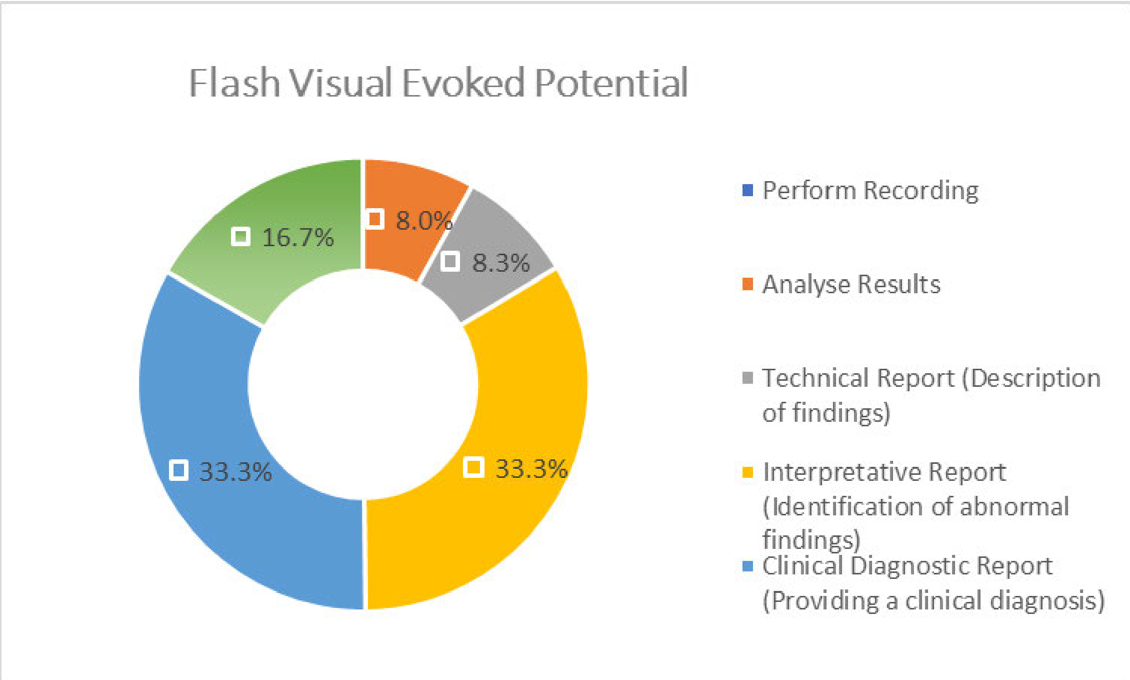


Figure 4.17: FVEP outcome skill level

4.5.1.3 Neuromuscular modality selections

Both EMG and NCS were selected for inclusion and further analysis. The initial independent modality of "Assisting with EMG" was incorporated as a lower level of skill in EMG. It was considered below the level of "Perform recording". This resulted in an adjusted rating scale of 6 levels of skill.

Grouped NM modalities received a total of 88 votes out of a combined 484 votes (18%). NCS received 57% (n = 50) of these votes and EMG received 43% (n = 38) (Figure 4.18). All 50 participants selected NCS as an essential modality and 76% indicated EMG should be included in the four-year degree. However, 41% of participants that selected EMG indicated the lower skills level of "assist with EMG".

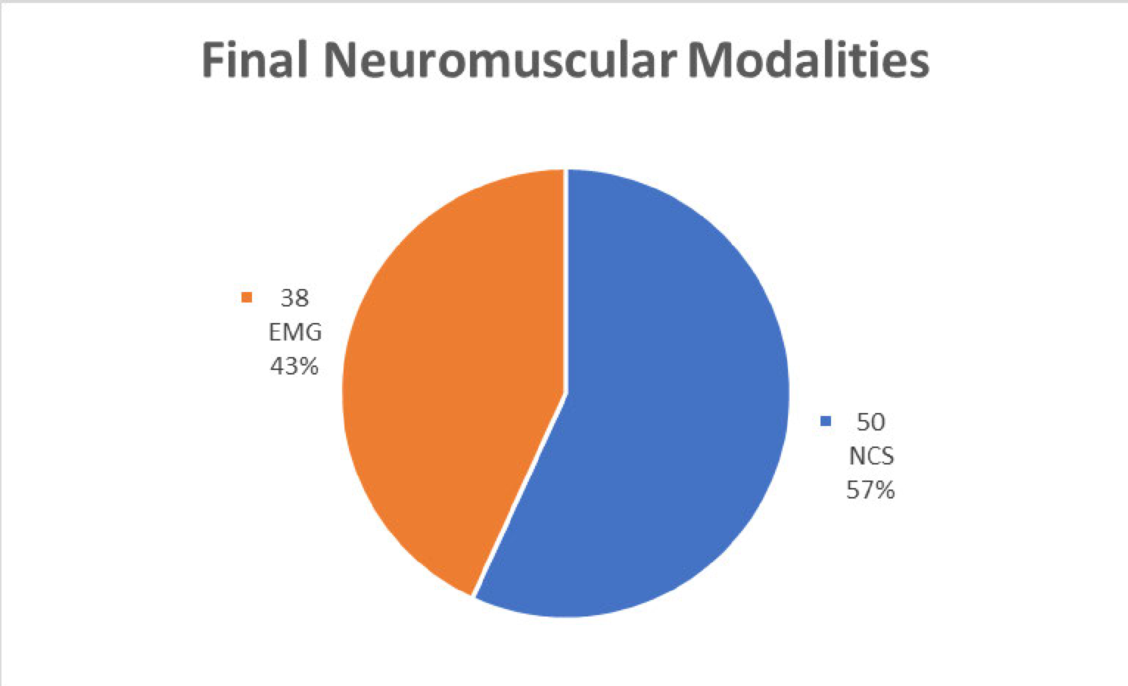


Figure 4.18: Final neuromuscular modality selection frequency

4.5.1.3.1 Outcome skill levels for NM modalities

Nerve conduction studies were scored on a five-point Likert scale. Electromyography was scored on a modified six-point scale to accommodate the lower skill level of assisting with EMG.

1 = Assist with EMG

2 = Perform recording

3 = Analyse results

4 = Technical report writing

5 = Interpretative report writing

6 = Clinical report writing

Electromyography: The rounded mean score was 3 and the median score was 2.

Nerve conduction studies: The rounded mean score, and the median score was 4.

- The modal OSL selection for EMG (Figure 4.19) was assist with recording. The PA was poor at 47% PANRM, 50% with the rounded mean, and only 33% with the median score (Table 4.5).
- The modal OSL selection for NCS (Figure 4.20) was interpretative reporting. The PANRM was 71%. The PA with the rounded mean and median rating was 80% (Table 4.5).

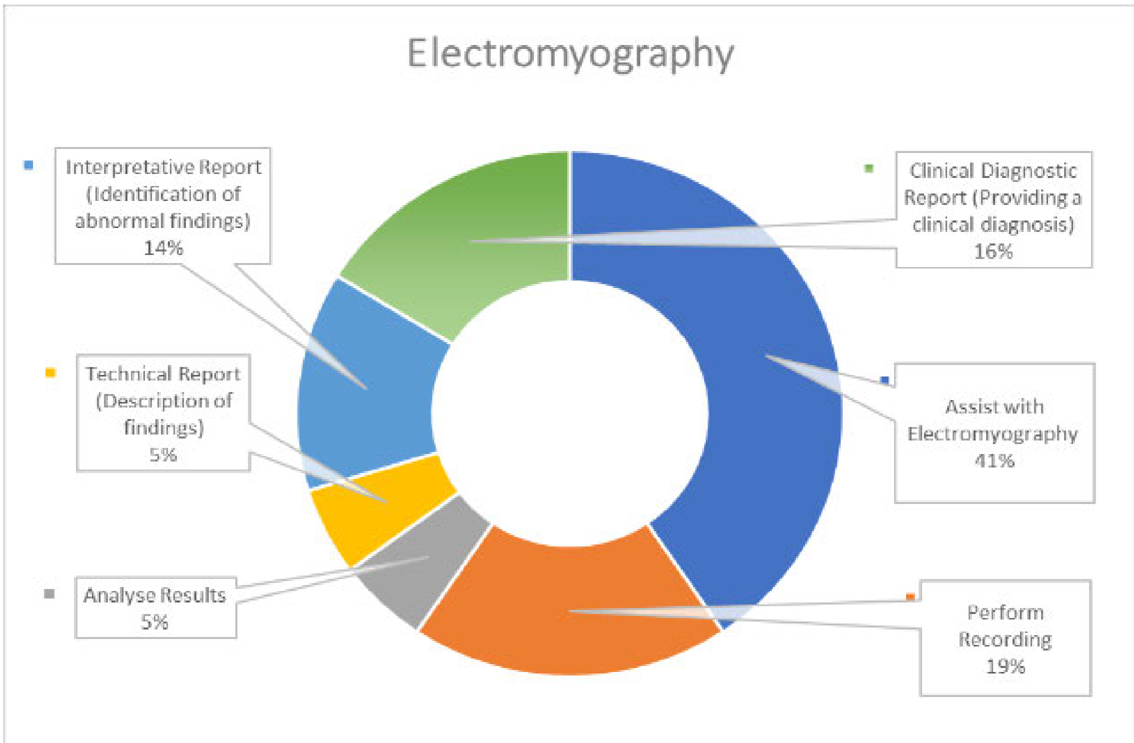


Figure 4.19: EMG outcome skill level

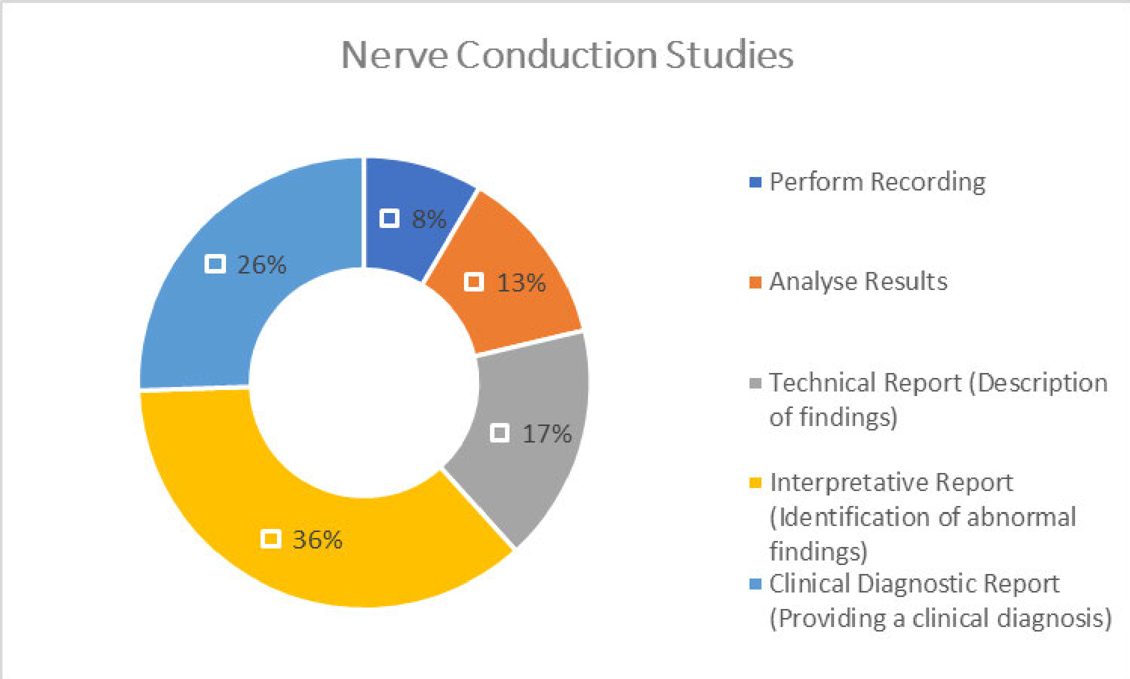


Figure 4.20: NCS outcome skill level

4.5.1.4 Sleep modalities

Of the original three sleep modalities PSG and MSLT were selected for inclusion and further analysis (Figure 4.21) and NIV PAP was added as an additional modality. Grouped sleep modalities received a total of 88 votes out of a combined 484 votes (18%). PSG received 57% (n = 48), MSLT 42% (n = 36, and NIV PAP received 1% for the single additional modality selection.

Maintenance of wakefulness testing received only 3 votes which all came from the participants with more than ten votes.

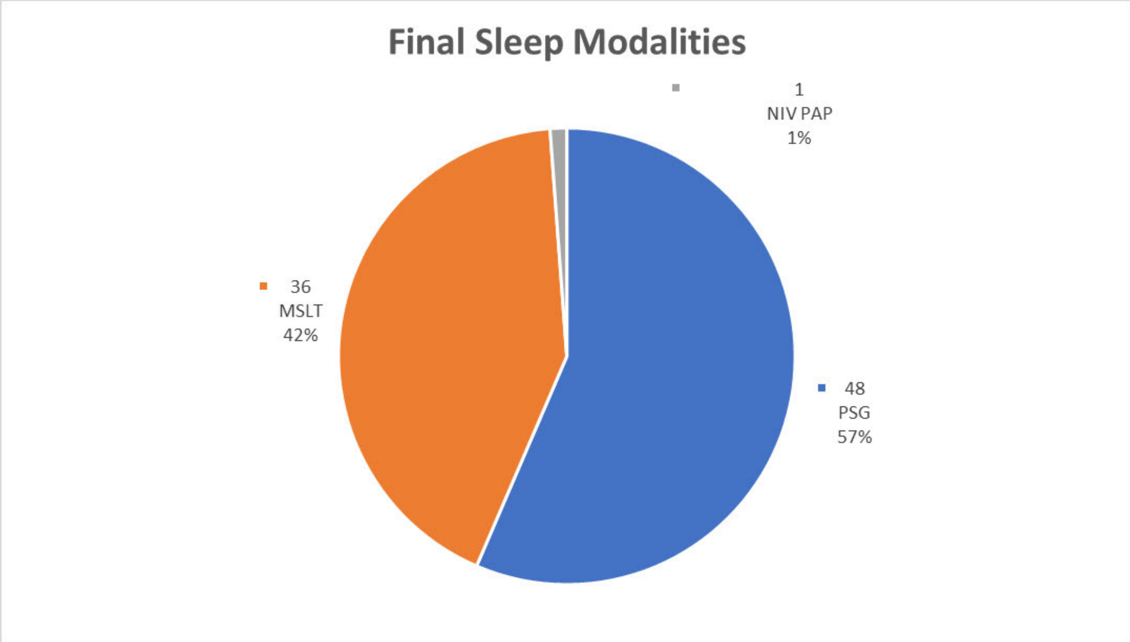


Figure 4.21: Final sleep modality selection frequency

4.5.1.4.1 Outcome skill levels for sleep modalities

Polysomnography and MSLT both showed a rounded mean score of 4, and a median score of 5.

Non-invasive positive airway pressure: The single skills comment was "… make recommendations on both CPAP (Continuous Positive Airway Pressure) and non-invasive positive pressure ventilation (CPAP various modalities)". This was assigned a score of 5, equal to a skill of clinical reporting.

- The modal OSL selection for PSG (Figure 4.22) was clinical diagnostic reporting. The PANRM was 83% (Table 4.5).
- The modal OSL selection for MSLT (Figure 4.23) was clinical diagnostic reporting. The PANRM was 79% (Table 4.5).

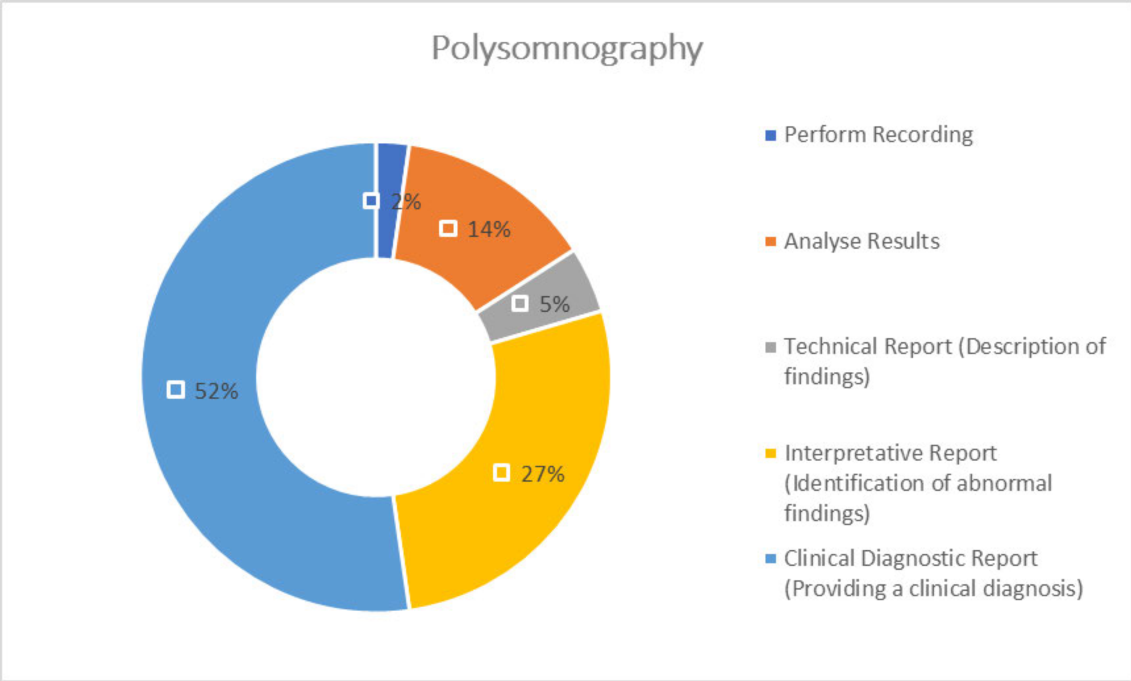


Figure 4.22: PSG outcome skill level

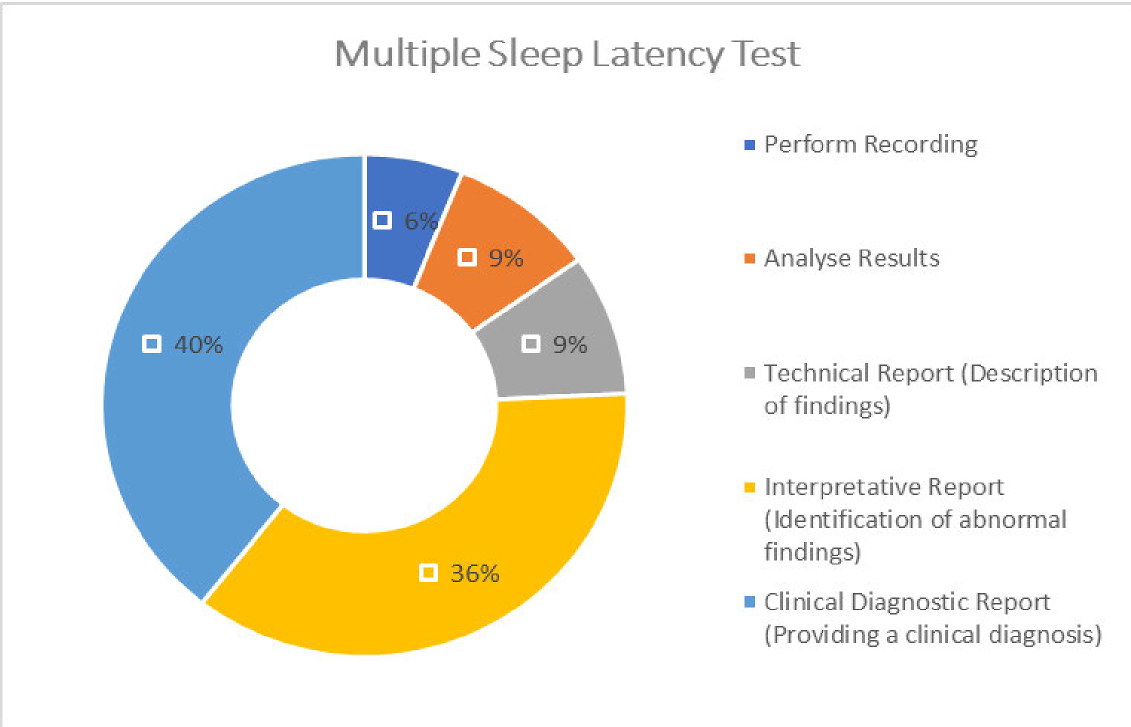


Figure 4.23: MSLT outcome skill level

4.5.1.5 Long-term monitoring modality selections

All three long-term monitoring modalities were included for further analysis (Figure 4.24). Surface electrode LTEM and cICU EEG scored nearly equally in importance. Grouped LTM modalities received a total of 69 votes out of a combined 484 votes (14%). Surface electrode LTEM received 39% (n = 27) of these votes, cICU EEG received 38% (n = 26), and SG LTEM received 23% (n = 16) votes.

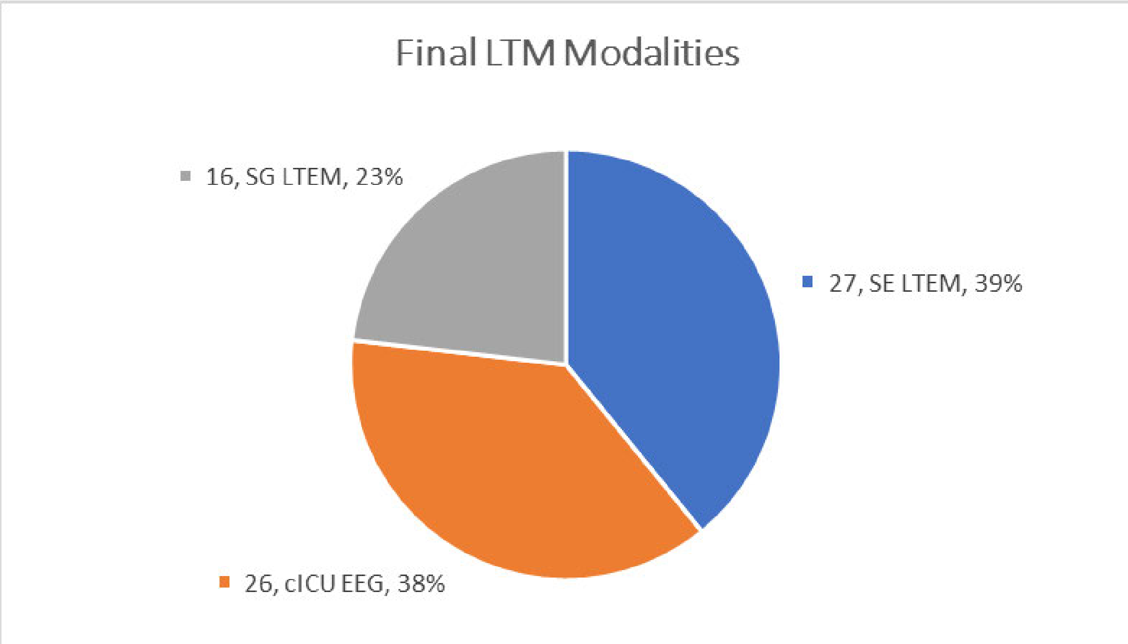


Figure 4.24: Final LTM modality selection frequency
Abbreviations: EEG – electroencephalogram; LTM – long-term monitoring; LTEM – long-term epilepsy monitoring; SE – surface electrodes; SG – subdural grid electrodes

4.5.1.5.1 Outcome skill levels for LTM modalities

Surface electrode LTEM, cICU EEG, and SG LTEM all had a mean rounded score of 4, and a median score of 4.

- The modal OSL selection for SE LTEM (Figure 4.25) was interpretative reporting. The PANRM was 72%. The PA with the rounded mean and median rating was 80% (Table 4.5).
- The modal OSL selection for cICU EEG (Figure 4.26) was interpretative reporting. The PANRM was 72%. The PA with the rounded mean and median rating was 80% (Table 4.5).

- Majority OSL selection for SG EEG (Figure 4.27) was clinical diagnostic reporting. The PANRM was 73%. The PA with the rounded mean and median rating was 80% (Table 4.5).

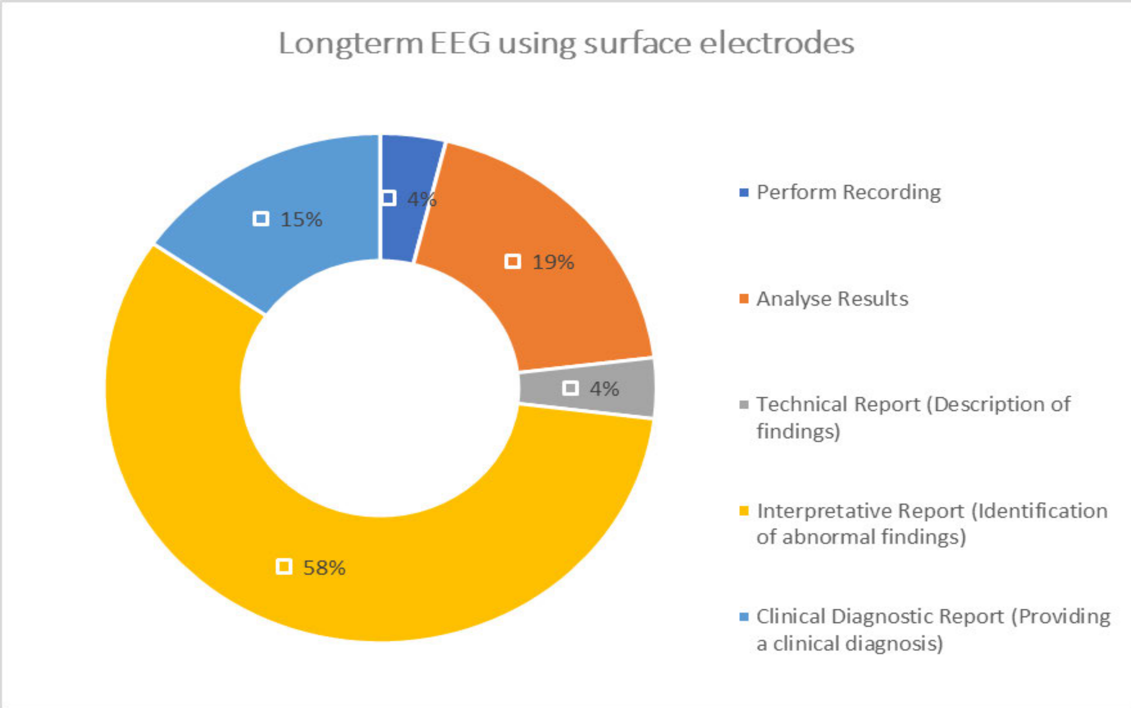


Figure 4.25: SE LTEM outcome skill level

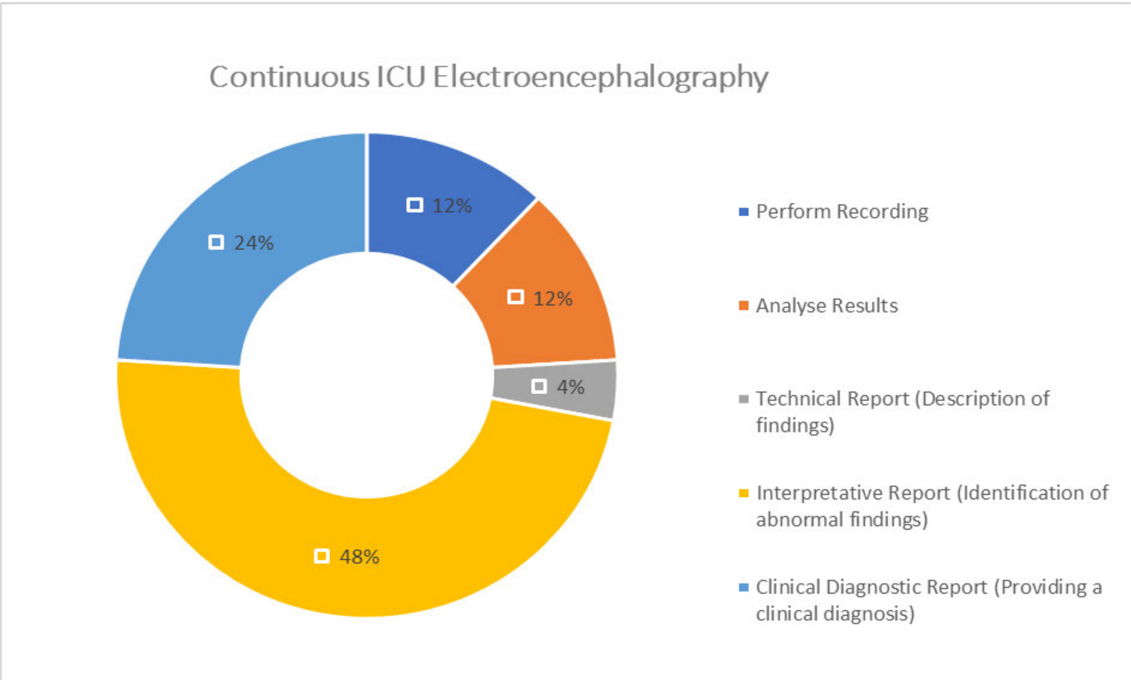


Figure 4.26: cICU EEG outcome skill level

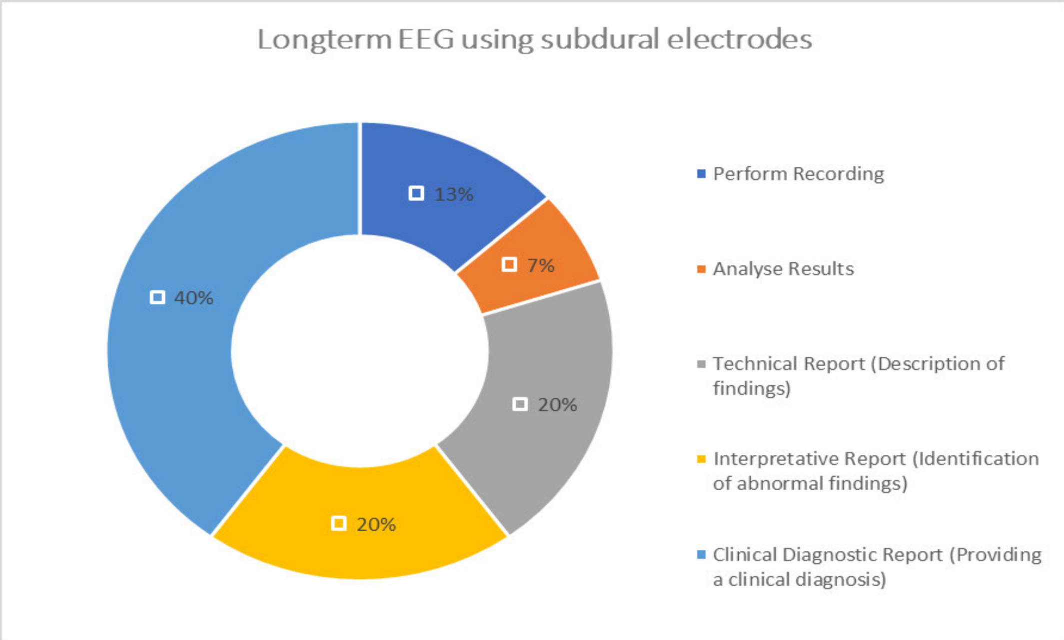


Figure 4.27: SG LTEM outcome skill level

4.5.1.6 Intraoperative monitoring modality selections

Of the original three IOM modalities, only IONM was selected for inclusion and further analysis. Intraoperative neuromonitoring received a total of 19 votes out of a combined 484 votes (4%) from a total of 38% of the 50 participants.

4.5.1.6.1 Outcome skill level for intraoperative neuromonitoring

The OSL for IONM was scored on an 8-point Likert scale (Figure 4.28). The additional skills levels were developed from a round-table industry discussion held in Johannesburg on 28 September 2019.

These were:

1 = Not applicable to undergraduate training
2 = Theoretical background only
3 = Clinical observation (no patient contact)
4 = Set-up recording under supervision (basic patient contact)
5 = Plan and set-up recording (observe monitoring)
6 = Monitor under supervision (identification of abnormal findings)
7 = Independently monitor (analyse results)
8 = Interpretative report (independently provide feedback to surgeon)

The rounded mean score for IONM was 6, however the median score was 1 and the modal OSL was 8 (selection frequency of 47%). The PANRM was 77% (Table 4.5).

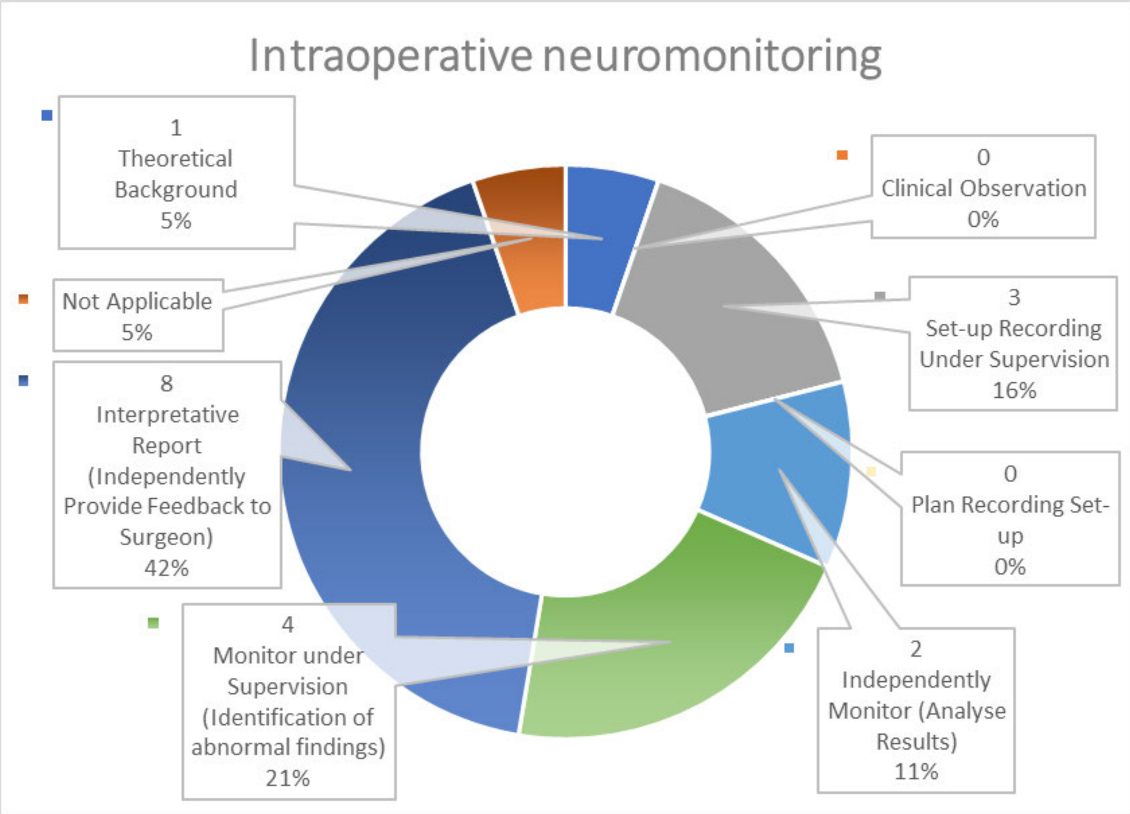


Figure 4.28: IONM outcome skill level

4.5.2 Outcome skills level consensus to majority, rounded mean, and median selection scores

Table 4.5 summarises the outcome skills selection consensus measure statistics. The majority selection category and the rounded mean rank score are equal for 10 of the 16 modalities (63%). The median score differs only twice (EMG and SG LTEM). The only modality where the non-rounded mean, rounded mean, and median were all different was IONM. The greatest agreement over all modalities was with the median OSL selection.

Polysomnography showed the highest PANRM at 83%, while EMG was lowest at 47%. All other modality agreement levels, except for FVEP, were within 1% to 4% of consensus.

When using the median selection rank only, EMG (33%) and FVEP (70%) did not reach consensus threshold. The coefficient of variation (COV) is > 0.5 only for EMG.

Electromyography and IONM had the largest SD at 1.96 for EMG and 2.19 for IONM. Bedside EEG showed the smallest SD at 0.96 (Table 4.5).

Convergence of COV and SD was retested during Q2 to test for an increase in consensus.

Table 4.5: Comparison of majority skills selection, rounded mean score, and mode with percentage agreement values for Questionnaire 1.

Modality	Majority outcome level (Mode)	Majority Score	Mean outcome level	Mean score	SD	95% Confidence interval	PANRM	Rounded mean score	PA rounded mean	Median outcome level	Median score	PA with median	**Coefficient of variation
NCS	Interpret	4	Interpret	3.57	1.25	3.218 - 3.931	71	4	80	Interpret	4	80	0.35
PSG	Clinical	5	Interpret	4.14	1.15	3.796 - 4.477	83	4	80	Clinical	5	100	0.28
Routine EEG	Interpret	4	Interpret	3.63	1.11	3.294 - 3.975	73	4	80	Interpret	4	80	0.31
Neonatal EEG	Interpret	4	Interpret	3.73	1.12	3.389 - 4.074	75	4	80	Interpret	4	80	0.30
EMG	Assist	1	Analyse	2.81	1.98	2.180 - 3.441	47	3	50	Perform	2	33	0.71
MSLT	Clinical	5	Interpret	3.94	1.20	3.531 - 4.348	79	4	80	Interpret	4	80	0.30
Bedside EEG	Interpret	4	Interpret	3.88	0.96	3.551 - 4.206	78	4	80	Interpret	4	80	0.25
BAEP	Interpret	4	Interpret	3.60	1.07	3.217 - 3.983	72	4	80	Interpret	4	80	0.30
SSEP	Interpret	4	Interpret	3.62	1.21	3.181 - 4.060	72	4	80	Interpret	4	80	0.33
SE LTEM	Interpret	4	Interpret	3.62	1.10	3.193 - 4.038	72	4	80	Interpret	4	80	0.30
cICU EEG	Interpret	4	Interpret	3.60	1.32	3.081 - 4.119	72	4	80	Interpret	4	80	0.37
PRVEP	Interpret	4	Interpret	3.61	1.16	3.136 - 4.082	72	4	80	Interpret	4	80	0.32
IONM	Interpret	8	Supervised	6.16	2.19	5.172 - 7.144	77	6	75	Independ	7	88	0.36
SG LTEM	Clinical	5	Interpret	3.67	1.45	2.934 - 4.399	73	4	80	Interpret	4	80	0.39
FVEP	Technical/ Interpret	3 and 4	Technical	3.42	1.16	2.758 - 4.076	68	3	60	Technical/ Interpret	3.5	70	0.34
*NIV PAP	Clinical	5	*	*	*	*	*	*	*	*	*	*	***

Abbreviations: BAEP – brainstem auditory evoked potential; EEG – electroencephalogram; cICU EEG – continuous ICU EEG; FVEP – flash visual evoked potential; IONM – intraoperative neuromonitoring; SG LTEM – long-term EEG monitoring with subdural grid electrodes; SE LTEM – LTEM using surface electrodes only; MSLT – multiple sleep latency test; EMG – electromyography; NCS – nerve conduction studies; SSEP – somatosensory evoked potential; NIV PAP – non-invasive ventilation positive airway pressure.

* No descriptive statistics values due to a single nomination of an additional modality

** Coefficient of variation of the mean (COV) of $\leq$ 0.5 indicates reasonable internal agreement (von der Gracht 2012).

*** Requires minimum of two values to calculate.

• Red text indicates values where no consensus measures were met, or internal disagreement was found.

4.6 Qualitative skills questions

Participants' text statement contributions regarding practical, theoretical, and knowledge skills required of BHS graduate addresses the second and third aim and objective and research question two as contained in Table 1.1 and Table 1.2.

4.6.1 Thematic analysis of qualitative statements

In the current research overlapping themes between practical and theoretical skills contributions were identified during thematic analysis. To better classify participant statements, the following questions were asked: "Do" vs "Know" vs "Are". All skills answering the "Do" question were classified as a practical skill, all skills answering the "Know" question were classified as a theoretical knowledge skill, and any skills conforming to the "Are" statement were classified as a personal or graduate attribute.

During analysis it became apparent that functions, duties, skills, and attributes were not clearly modality specific. Due to the non-randomised presentation of selected modalities (alphabetical order was used), the modalities presented first received more statements than others. This is attributed to participant fatigue from the recurrence of recurrent overlapping themes and natural attrition. Statements were therefore categorised in aggregate rather than modality related. Modality relationships were retested during Q2.

4.6.2 Practical skills and graduate attributes

Participants contributed a total of 1 518 comments. Most comments consisted of single statements. There were multiple instances where participants entered several statements combined as a single initial comment rather than five separate comments. These multi-theme comments were manually divided into individual statements and analysed separately. The true number of single statements were therefore increased beyond 1 518.

There was considerable overlap between the "theoretical skills" and "practical skills, and between "practical skills" and "graduate attributes".

All statements were read multiple times and evaluated according to the KT functions, duties, tasks and related activities (Table 3.4) (Human 1996).

Table 4.6 presents a summary of all condensed thematic statements.

There were five final condensed thematic categories: quality control, analysis, perform, management, and communication. Performance reflected the largest number of embedded practical skills. The categories of training and research as defined in 1994 were not represented.

During Q2 each group of skills were presented to participants to indicate if a particular modality relationship exists.

When contributing to BAEP practical skills, one participant added tone-burst recordings as part of routine BAEP testing. Conventionally broadband click stimuli are used in evaluation of neurological function and tone-burst stimulation in audiological evaluations. This was interesting and raised the question of whether this is, or should be, a standard practice. A review of historic practices scopes revealed that no specific mention of stimulus techniques was included. A question was added to Q2 to address this uncertainty.

Eight comments mentioned one or more type of NIV PAP treatment as part of the PSG skills contributions. This again raised the question of whether NIV PAP is a separate modality or an embedded skill to the modality of PSG. A question was added to Q2 to investigate if consensus exists regarding the relationship between PSG and NIV PAP.

Table 4.6: Condensed CN outcome practical skills and graduate attributes

	Quality Control	Analysis	Performance	Communication	Management	Personal graduate attributes
1	Troubleshooting and correction: technical problems (Example: equipment position, hardware and software)	Pattern recognition: Identifying Normal	Manage patient events/emergencies	Bedside manner: Patient interaction/communication	Maintain records/documentation of procedures	Teamwork
2	Troubleshooting and correction: physiologic patient related factors (Example: level of consciousness and focus)	Pattern recognition: Identifying Abnormal	Manage side effects to testing or treatment	Communicate staff, Doctors, nurses and colleagues	Room preparation/plan	Professionalism/ work ethic
3	Recognition and correction of ICU Specific Artefact	Recognition and measurement of wave forms/calculations	Adjust protocol to obtain relevant information to question (Example: placing additional electrodes)	Communicate with hearing disability	Calibration and maintenance and testing of equipment	Enthusiasm
4	Artefact recognition/differentiation from activity of interest: Correction; physiologic	Interpret/Compile report: written or verbal: include recording limitations	Equipment machine knowledge/ setting manipulation (Example: Changing filters, programming amplifiers)	Obtain cooperation/all ages/ explain procedure/	Self-development- stay up to date with developments	Handle difficult patient
5	Artefact recognition/differentiation from activity of interest: Correction; non-physiologic	Integrate results from multiple tests (NCS/EMG)	Needle Electrode Placement Recording: (skilful application/hook-up/ accurate and technically correct)	Intensive Care Unit protocols - work with ICU staff	Data collection and management	Be receptive
6	Apply Protocol/minimum standards in all environments and all patients	Diagnosis / Classify disease	Surface Electrode Placement Recording: (skilful application/hook-up/ accurate and technically correct)	Theatre protocols - work with Theatre staff	Protocol and procedure development	Critical thinking
7	Replication (averaging) of waveforms during recordings	Apply Anatomy	Needle Electrode Placement Stimulating: (skilful application/hook-up/ accurate and technically correct)	Theatre procedure and practices		Adaptability
8	Repeatability of serial tests	Apply Physiology	Surface Electrode Placement Stimulating: (skilful application/hook-up/accurate and technically correct)			Ability to concentrate for long periods of time
9	Intensive Care Unit: neat and out of the way set-up of equipment – work around equipment	Apply Pathophysiology	History/ pre-test evaluation			Be focused, time management/ organised method
10	Clean electrode sites: Impedances	Understand treatment options	Choose correct stimulation choice			Perform under pressure
11	Aseptic Infection control and safety	Correlating recording with video	Understand/ choose/ modify montages			Steady hands/ Dexterous/ Fine motor control

	Quality Control	Analysis	Performance	Communication	Management	Personal graduate attributes
12	Sterile Infection control and safety	Effect of Medication/Drugs	Surface RECORDING techniques			Recognise personal limits and obtain assistance
13	Accurate distance measurement	Indication of drugs	Needle RECORDING techniques			Experiencing the test procedure to understand patient experience
14	Measure 10-20 system	Identifying sleep features	Surface STIMULATION techniques			Listening
15	Annotations (monitor patient, recording, skilful, drugs, structural defects)		Needle STIMULATION techniques			Confidence without Arrogance
16	Adjust to new research/ standards		Patient Preparation: (safe patient manipulation/ correct positioning/ dignity/ mobility/ comfort)			Work with different age groups
17	Electrical safety		Recognise and capture Waveforms			Work with different personalities (patients and colleagues)
18	Care of electrode placement site (Invasive and non-invasive)		Personal Positioning: (comfortable and stable)			Stay calm
19	Manage/control SLEEP during recording		Appropriate Activation procedures			
20			Work with Collodion or similar			
21			Setup video recording			
22			Manage sp02 and intubation			
23			Ambulatory recording			
24			Assess VA (Visual Acuity)			

4.6.3 Theoretical knowledge skills

A summary of the 74 theoretical knowledge contributions made by participants in Q1 is presented in Table 4.7.

Using the “know” question during thematic analysis, the 74 knowledge skills in Table 4.7 were identified. These were recurrent over multiple modalities, and no specific modality relationship could be formulated without further input from industry specialists. These were presented during Q2 for assessment regarding modality relationship and outcome year for achievement, or rejection as a non-essential skill for an undergraduate degree.

Table 4.7: Condensed CN outcome theoretical knowledge skills

	Knowledge skills
1	General electrophysiologic recording principles (acquisition, averaging, display)
2	Know differences of related modalities (Example the different evoked potential tests)
3	AASM sleep staging and related event scoring
4	Importance GA and CA (Know how to calculate)
5	Functions and method of working of ancillary ICU/theatre equipment (bispectral index/aneurism detection/cerebral function monitor/patient safety indicators)
6	ACNS/IFCN protocols (minimum technical requirements) for all modalities
7	Treatment pertaining to modality
8	Pathophysiology and diseases/diagnosis pertaining to modality (dysfunction of anatomy being tested, including interrelated organ systems affecting anatomy under investigation)
9	Anatomy pertaining to modality (physical location and connection/relation of structures)
10	Physiology pertaining to modality (generation of activity - function of the anatomy)
11	Pathology expected from clinical presentation
12	Indication of testing / clinical application
13	Contra-indication and side-effects of testing
14	Normal results (normative data)
15	Clinical presentation to expect of known pathology
16	Electrophysiological presentation of normal physiology (normal results -patterns)
17	Electrophysiological presentation of pathology (abnormal results - patterns)
18	Effect of UNRELATED pathology on test results
19	Localisation of lesions (identify anatomical location)
20	Identification of sedation and outpatient medication effect on recording
21	Identification of in-hospital medication effect on results
22	Aspects of history taking
23	Adjust protocol to obtain appropriate information according to history
24	Identify critical abnormalities requiring immediate medical intervention (status epilepticus)
25	Psychopathology (Functional neurologic disease, Psychogenic non-epileptic seizures, malingering)
26	Consider effect of patient's mental state

	Knowledge skills
27	Identify and use clinical pathology to guide recording
28	Correlate abnormal electrophysiology with underlying dysfunction and cause of dysfunction
29	Electrophysiological correlation with radiography result
30	Equipment variables effect on results (technical: non-physiological)
31	Patient variables effect on results (technical and physiological)
32	Recording variables' effect on results
33	Anaesthesia
34	Give diagnosis and suggest additional investigations: (example: bloods and imaging)
35	Research
36	Knowledge and understanding of surgical procedures understanding of surgical procedures
37	Sensitivity and specificity of testing
38	Limitations of test modality - practical and medical
39	Disease specific testing protocols (example: CIDP; optic neuritis; BRECTS)
40	Technical aspects in recording or stimulation
41	Calculations of all values and parameters of stimulus, recording, and results (example intensity, luminescence, loudness, sleep duration etc)
42	Clinical utility of different recording parameters - what physiology is assessed through each parameter or sensor
43	Differential amplification
44	Digitisation of recordings (example, analog to digital conversion)
45	Importance of low and equal Impedances
46	Age related maturation of electrophysiology results
47	Age related abnormalities
48	Correlate abnormal electrophysiology with CLINICAL presentation of patient
49	Software data manipulation to assist analysis (Example use and effect of filters and display settings)
50	Equipment function and set-up
51	Differentiation between physiological and artefactual electro signal recording
52	Importance of technical sufficient recording
53	Principles of measurement (example: international 10-20, Queen Square etc)
54	Causes of, and methods of elimination, of artefacts/faults
55	Prognostication - clinical implication of findings
56	Electrical safety
57	Indication and results of activation procedures / appropriate stimulation in non-responsive
58	Importance and methods of calibrations –patient
59	Importance and methods of calibrations –equipment
60	Identification of EEG frequency bands during recording
61	Aspects of report writing
62	Equipment hardware and software options
63	Neuropharmacology
64	Electrode types
65	Montages – choices, indication, effect on results etc.
66	BLS/CPR
67	Identify and measure all components of responses (example: peaks, morphology etc.)

	Knowledge skills
68	HPCSA guideline on ethics and practice
69	Scope of profession
70	Scope of practice
71	Ethical billing
72	Medical negligence
73	Theory introduction on advance modalities or methods within modalities (example: BAEP steady state / multi-modality evoked potential IOM / VEP sinewave grating)
74	Clinical grading scales

4.6.4 Minimum clinical exposure to master a modality

Some participants included minimum exposure numbers for mastering of the modality as a practical skills statement. Table 4.8 summarises the minimum exposure contributions made during answering of skills and knowledge open ended statements. As seen several comments mentioned "sufficient" exposure without quantification. The question regarding minimum procedure numbers, or clinical exposure, was further addressed in Q2 and assisted in answering aim and objective four and research question three.

One participant specifically noted that 95% should be considered a pass for IONM. This information was used in development of Q2 for further evaluation. Not all modalities received comments regarding minimum exposure. Only modalities that received comments are included in Table 4.8.

Table 4.8: Essential modality minimum exposure from Q1

Modalities	Minimum clinical exposure
NIV n=1	Sufficient for proficiency
BAEP **n**=1	30
Mobile EEG n=1	300
EMG n=2	Join all. Sufficient for proficiency
IONM n=2	30 Supervised cases Postgraduate: 50-100 supervised cases
NCS n=1	50
PRVEP n=1	30
PSG n=2	100 Sufficient for proficiency
EEG n=1	300
SSEP n=1	50
Neonatal EEG n=1	20

4.7 Introduction to Q2 results

Questionnaire 2 aimed to test agreement on new items that arose from Q1. It further tested agreement on essential modalities and graduate outcomes for an undergraduate degree in CN.

Questions in Q2 followed the same category order as in Q1. After inclusion and demographic questions participants were presented with Q1 results for consideration of agreement and opportunity for re-evaluation of their own selections.

Questionnaire 2 investigated possible division of outcome goals to either third or fourth year of study and the minimum number of procedures needed to achieve the desired graduate OSL.

The interdependency of modalities for learning was investigated to confirm prerequisite and dependent skills and modalities. This information was used in the development of a modality-based framework of standardised order of practical TLA.

4.8 Sample statistics for Q2

During email distribution of Q1 five contacts opted out from receiving further email invitations. Several contacts were added during Q1 as respondents could nominate an additional or alternative email address for follow-up reminders and invitations. Questionnaire 2 invitations were sent to this modified distribution list as saved in the online QP distribution desktop. As previously described this list included non-CNPs and KT-Ss. The first questions after consenting to participation addressed inclusion criteria. This was followed by demographic questions to better define the characteristics of participants.

4.8.1 Completion rate

A total of 38 potential participants consented to participate. One potential participant consented to participation but did not answer any questions. One participant was a KT-S and the questionnaire auto-terminated with a thank you message. A total of 36 participants fulfilled the inclusion criteria and 30 completed the final question. This is an overall completion rate of 83%. One participant did not contribute to essential modality selections or modality learning importance ranking. They did however complete the rest of the skills and modality matching questions.

Gender distribution stayed similar with 72% female participants and 28% male.

4.8.2 Health Professions Council of South Africa registration status

Of the HPCSA registered CNPs that participated in Q2, six participants indicated supervised practice registration (17%) compared to the three Q1 participants. Comparatively the percentage of practitioners with independent practice registration increased while the percentage of private practice practitioners decreased (Figure 4.29).

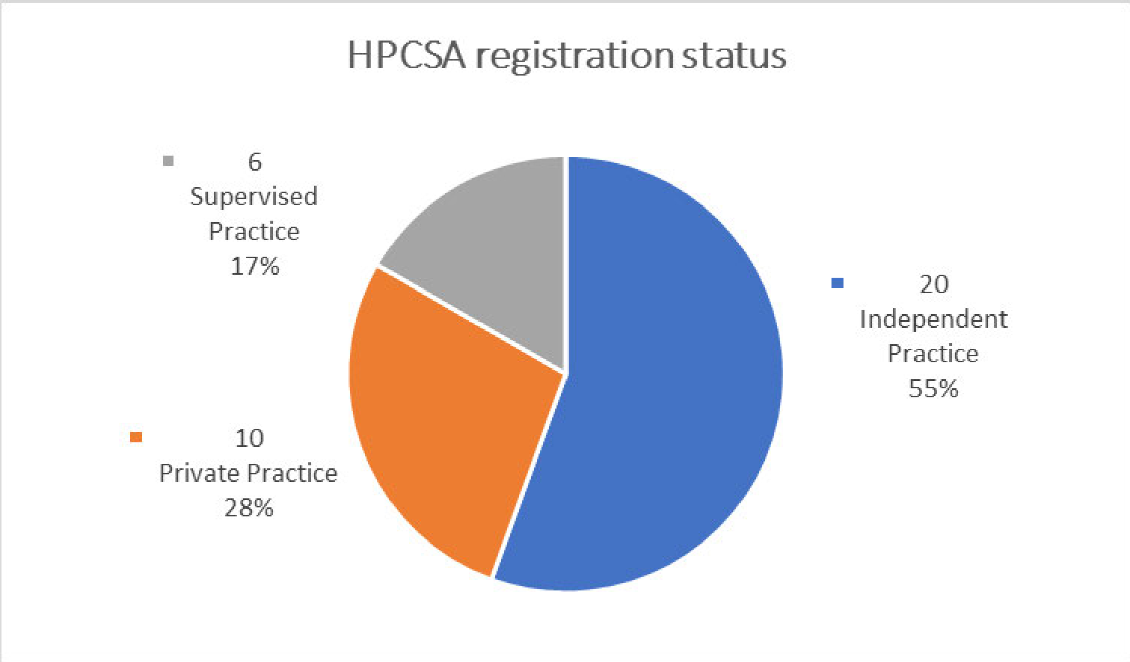


Figure 4.29: Q2 participants' HPCSA registration status

4.8.3 Post qualification experience and involvement in WIL training

Nearly two-thirds (n = 23, 62%) of participants reported having practiced in both private and government service since completing training, only 14% (n = 5) never worked in private practice (Figure 4.30).

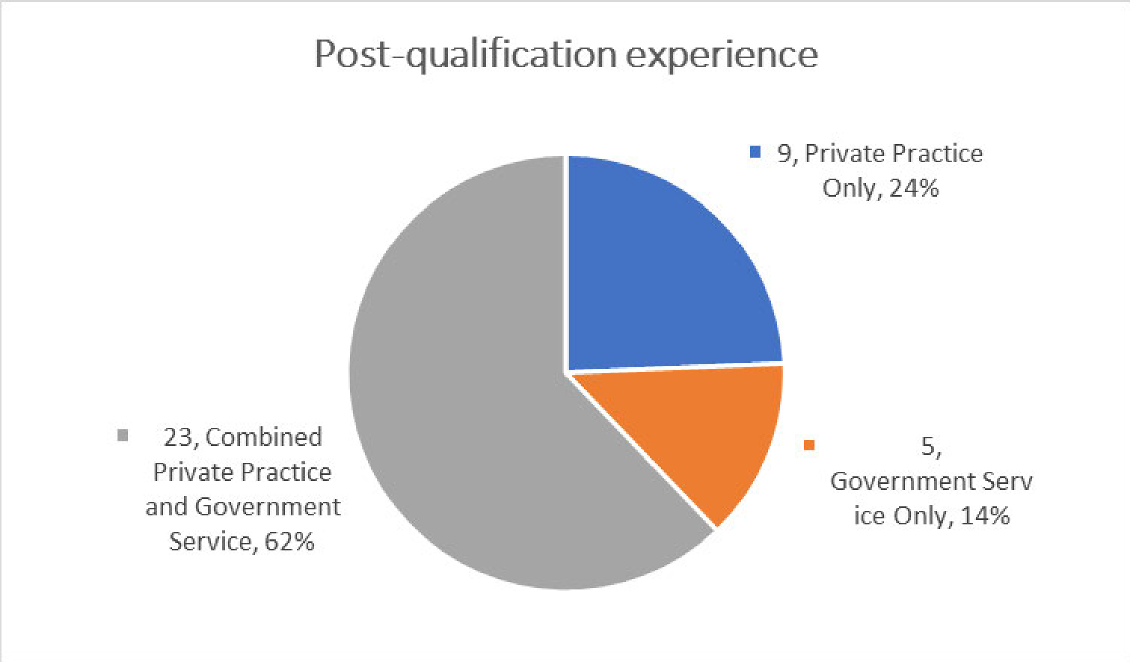


Figure 4.30: Q2 participants' post-qualification experience

A third of participants reported current involvement with KT-S WIL training (n = 12) and another 36% (n = 13) confirmed prior involvement with training (Figure 4.31). Thirty-one per cent of participants reported no current or prior involvement in KT-S WIL training.

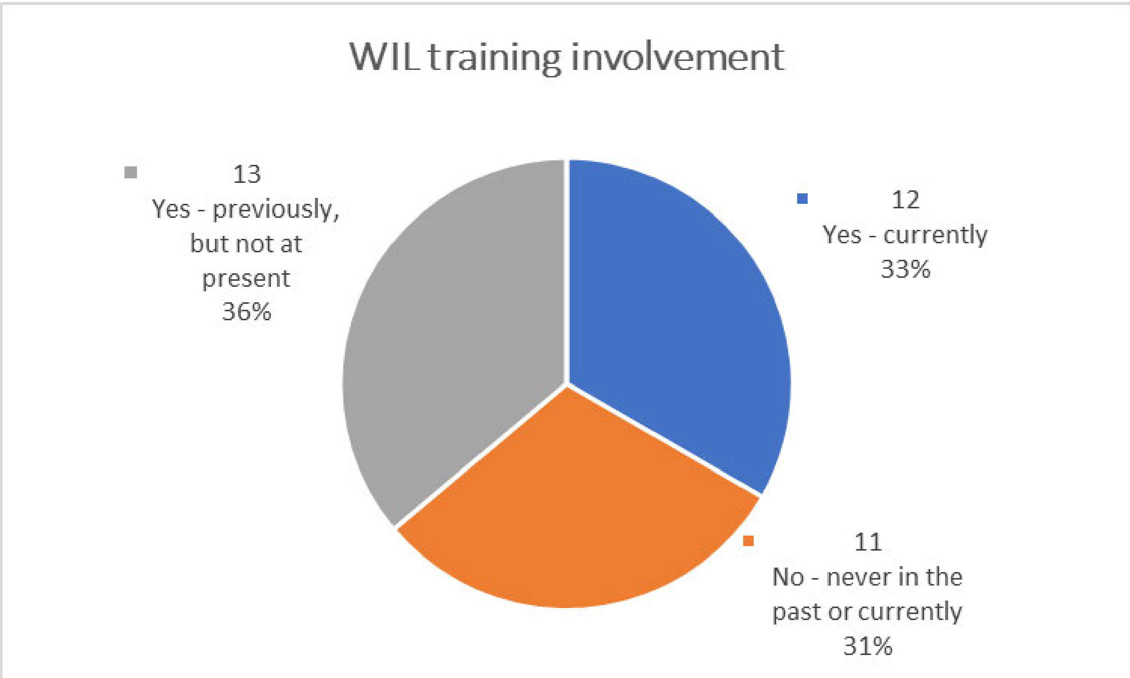


Figure 4.31: Student WIL training involvement

4.9 Questions arising from Q1

These questions address objective one and research question one – determination of core modalities.

4.9.1 Flash visual evoked potential

The first question arising from Q1 addressed the inclusion of FVEP as an essential modality in an undergraduate degree.

Participants were asked to indicate whether FVEP is essential for BHS graduates to master, or whether they believe it is an unnecessary modality. All 36 participants answered the question and 78% (n = 28) indicated that FVEP is an essential modality.

4.9.2 Non-invasive positive airway pressure therapy

During Q1 NIV PAP was added as an additional skill during the skills importance voting question. During the embedded practical and theoretical skills contributions 40 comments included NIV PAP as an embedded PSG skill.

To test consensus on this relationship participants were asked to select one of three options: NIV PAP is a separate modality, NIV PAP is a PSG skill, or NIV PAP is not applicable to an undergraduate degree. The results are displayed in Figure 4.32.

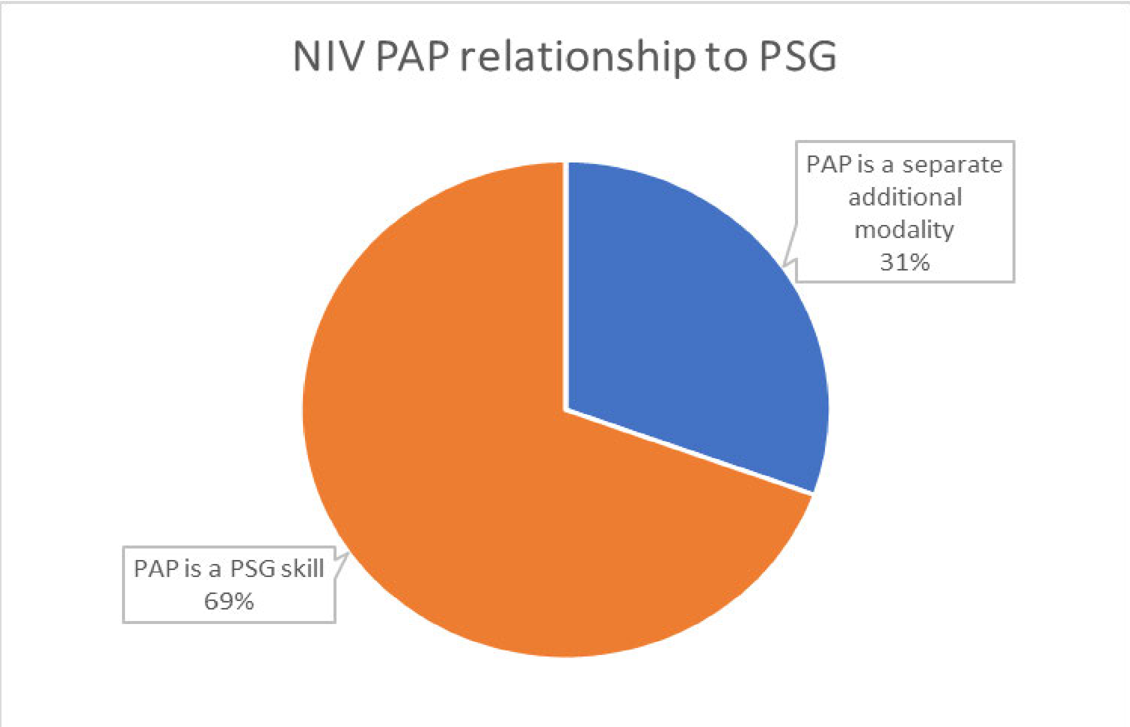


Figure 4.32: NIV PAP relationship to PSG

All 36 participants answered the question. The calculated mean score was 2.694 (± 0.5; 95% CI: 2.542 – 2.847), the median score was 3. Agreement with the mean (90%) and median value (100%) were supportive of NIV PAP as a PSG skill rather than an independent modality. Coefficient of variation (COV) was < 0.5 at 0.17.

Non-invasive positive airway pressure was not further investigated as a separate modality, but rather an embedded skill that need to be mastered for successful PSG graduate skill level outcome.

4.9.3 Tone-burst brainstem auditory evoked potential

During the practical skills contribution section of Q1 three skills comments indicated that BAEP using tone-burst stimulation should be taught or should be included as part of a standard BAEP examination.

Participants were presented with three options: “Graduates need only know BAEP with click responses”; “Graduates need only know BAEP with tone-burst responses”; or “Graduates need to know routine testing with both click and tone-burst responses”. A 78% percent majority (n = 28) indicated that graduates need to know both, and both should be included in routine testing (Figure 4.33).

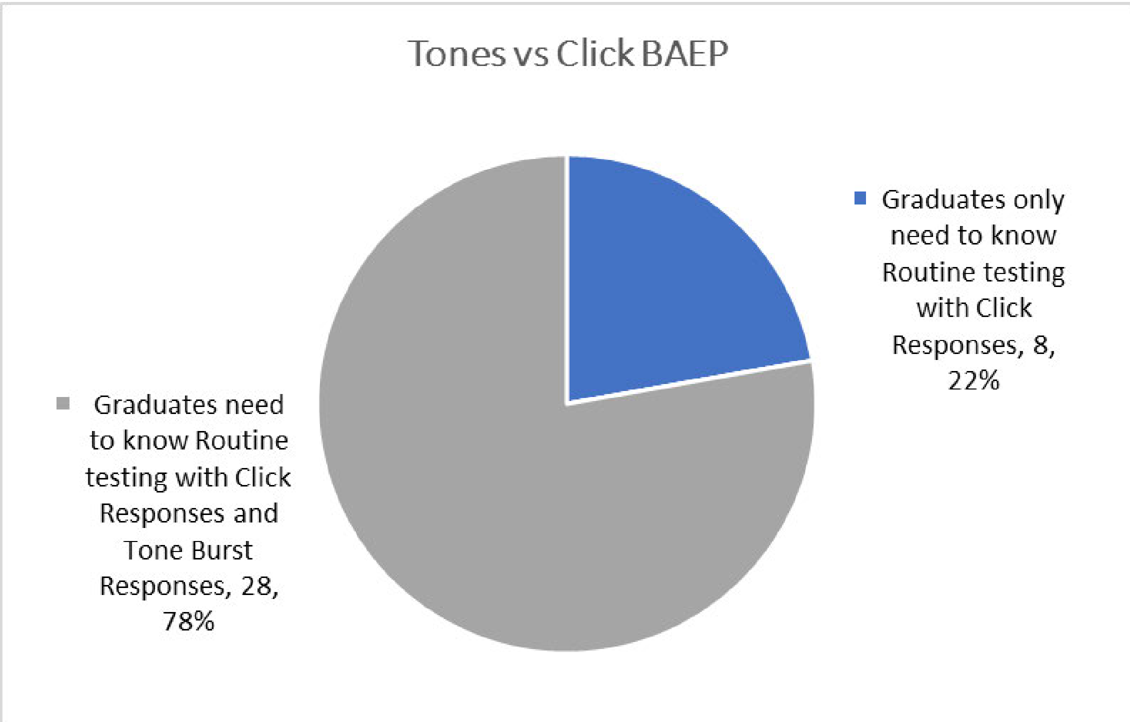


Figure 4.33: Tone vs click stimulation BAEP

All 36 active participants answered the question. The mean score was 2.556 (± 0.28; 95% CI: 2.280 – 2.831) and the median score was 3. This would indicate that both tone-burst and click responses should be taught as part of the undergraduate BHS.

4.10 Modality selection ranking according to importance for learning

Determination of how modalities relate to each other in importance and order of learning addresses the first and fourth aims and objectives and introduces research question three (Table 1.1 and Table 1.2). Research question one is also addressed.

Essential outcome modalities from Q1 were presented for rank order selection according to importance for learning.

Thirty-four participants contributed to modality ranking. Modalities were listed in decreasing order of average weighted rank (Figure 4.34).

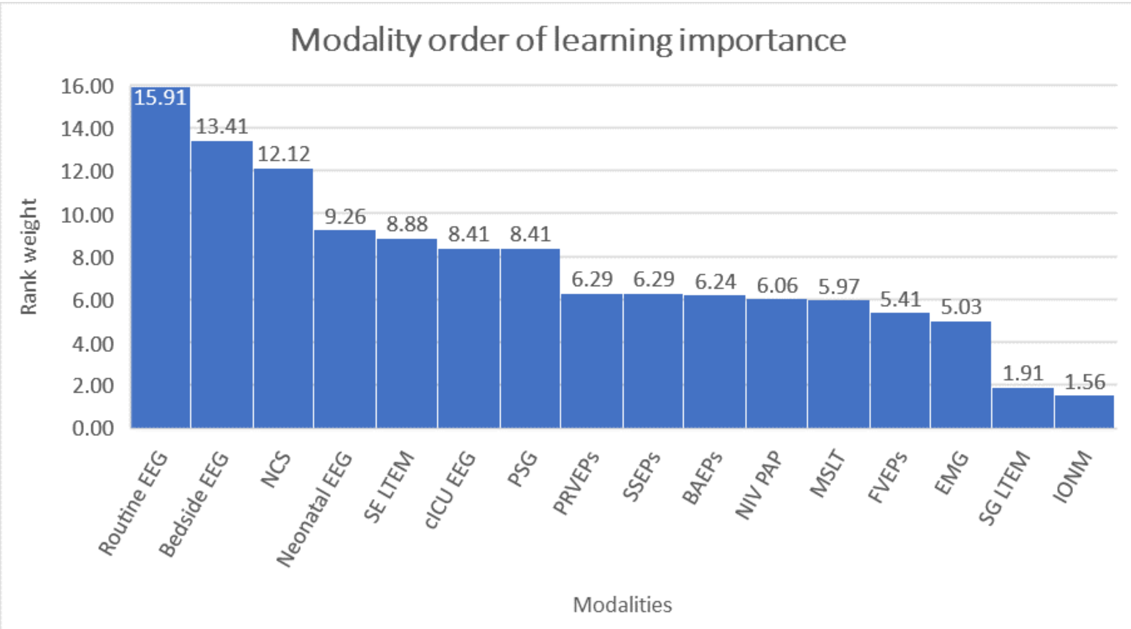


Figure 4.34: Modality ranking in order of learning

Rank percentile was used to determine which modalities were considered non-essential for learning during the undergraduate BHS WIL. The rank value cut-off for inclusion was 4.75 (See Table 3.5, Paragraph 3.13.1). Table 4.9 shows both the weighted rank values and the participant selection frequency per modality. The only two modalities that did not pass the threshold as essential for learning were SG LTEM (rank value 1.91) and IONM (rank value 1.56). Despite the < 75% participant selection frequency, EMG rank weight was above the importance for learning threshold.

Table 4.9: Modality importance for learning frequency and weighted rank

Modalities	Weighted Average	Number of participants	Participant frequency
Routine EEG	15.91	34	100%
Bedside EEG	13.41	31	91%
NCS	12.12	33	97%
Neonatal EEG	9.26	28	82%
SE LTEM	8.88	27	79%
cICU EEG	8.41	26	76%
PSG	8.41	30	88%
PRVEP	6.29	29	85%
SSEP	6.29	30	88%
BAEP	6.24	29	85%
NIV PAP	6.06	26	76%
MSLT	5.97	26	76%
FVEP	5.41	26	76%
EMG	5.03	21	62%
SG LTEM	1.91	14	41%
IONM	1.56	18	53%

4.11 Modality inter-related dependencies for learning

Questions 20 through 35 of Q2 explored the interdependence of essential modalities in facilitating learning of all other modalities during WIL.

Answering aim and objective one and four, and research questions two and three, requires us to know which modalities provide structure and support for learning of related modalities. Therefore it was theorised that singular or multiple modalities could also act as embedded skills required to master more complex modalities.

Thirty-two participants completed all modality interdependence questions, and these 32 response sheets were considered for analysis of questions 20 through 35.

All modalities that passed Q1 threshold as outcome modalities were included in the modality relationship questions. Electromyography passed the threshold for inclusion, while SG LTEM, and IONM did not pass the importance for learning threshold in Q2 as independent modalities, and NIV PAP was determined to be a PSG embedded skill.

Their importance for learning of other modality(ies) were considered possible and therefore were included in analysis but is not reported separately.

- The first aim of this question block was to determine the most essential dependent and prerequisite modalities for learning each individual modality.
- The second aim was to determine the learning importance rank order of dependence, or pre-requirement, of all related modalities. This would then start to build a learning framework (aim four of the study).

Both the participant selection frequency and the rank order for dependency, or pre-requirement, were evaluated and taken into consideration for framework development.

The frequency of selection, or selection rate, a modality received as either prerequisite or dependent was calculated using the number of participants (n = 32). All selection percentage values are therefore representative of the aggregate selection rate and reflect the power of the opinion of the total participant group.

The dependency, or prerequisite, learning importance rank of each modality was calculated using the mean rank scores from all selections in the dependent and prerequisite groups.

All modalities with a participant selection frequency relationship of more than 25% were evaluated for dependency or pre-requirement.

All prerequisite and dependent selections per modality were totalled to determine the overall inter-modality relationship power with the aim to:

- Find the modalities with greatest overall inter-modality relationship importance.
- Determine which modalities were selected as prerequisite most often.
- Determine which modalities were selected as dependent most often.

Each modality is reported individually, and the aggregate results can be found in Appendix 8.

4.11.1 Modality specific dependence and prerequisite inter-modality relationship analysis

This section reports the results of the relationship selection questions for each individual modality that passed Q2 importance rank threshold for inclusion as an essential outcome modality. Modality results will be reported in the same order as in Q1 results.

Tables were used to present the intramodality selection power relationships. Pareto charts were used to present these relationships graphically and use cumulative learning power contributions to highlight the importance order of the essential and useful modalities. Non-weighted average importance for learning ranks were also plotted on Pareto charts. An average rank of 1 represented total dependence and a rank of 0 total a-dependence.

Colour coding was used in tables and charts to highlight the degree of relationship or order of importance as follows:

- **Tables:**
  - Primary essential learning relationship power: All modalities with a ≥ 75% selection frequency, coded in light red with dark red text.
  - Secondary learning importance relationship power (part of useful many): Modalities with a relationship frequency of ≥ 50%; < 75%, coded in light yellow with dark yellow text.
  - Tertiary learning importance relationship power (part of useful many): Modalities with a ≥ 25%; < 50%, relationship selection frequency, coded in light green with dark green text.
  - Any modalities below the 25% representation level are seen as of trivial importance or non-related and coded in light grey with dark grey text.

- **Pareto Charts:**

Modalities with a ≥ 25% relationship power were evaluated for cumulative frequency importance and average rank score using Pareto charts.

Charts were generated for relative average importance rank scores. Three or more modalities with a ≥ 25% dependent or prerequisite relationship power were plotted on an average importance rank chart.

  - Modalities with an average rank importance above the third quartile (75th percentile) average rank relationship, were deemed essential and represented by blue bars.

Modalities below the Pareto line, and to the right of the first Pareto breakpoint, were determined to have gradually decreasing rank benefit in relationship to the modality being investigated. Modalities with an average rank in the interquartile range were considered useful for learning. These modalities were represented by green bars.

- Modalities in the first quartile with a < 25th percentile average rank relationship, or to the right of a clear Pareto breakpoint, were deemed as trivial and were represented by orange bars.

4.11.1.1 Electroencephalography modalities

4.11.1.1.1 Routine electroencephalography

Routine EEG received a total of 274 selections across all modalities. All selections classified routine EEG as prerequisite to all other modalities (Table 4.10).

Table 4.10: Routine EEG modality relationships

Modality relationship to Routine EEG	Count	Routine EEG Prerequisite frequency	Routine EEG Dependence frequency
Bedside EEG	32	32	0
SE LTEM	30	30	0
cICU EEG	29	29	0
Neonatal EEG	29	29	0
SG LTEM	26	26	0
PSG	26	26	0
MSLT	24	24	0
IONM	17	17	0
SSEP	15	15	0
BAEP	14	14	0
PRVEP	12	12	0
FVEP	11	11	0
NCS	8	8	0
EMG	1	1	0
Total	274	274	0

Table 4.11 shows the selection power relationships of the modalities selected as related to Routine EEG where Routine EEG was considered prerequisite to learning.

Routine EEG was selected as prerequisite by ≥ 25% of participants in relationship to all modalities except EMG.

Table 4.11: Routine EEG prerequisite power

Modality relationship to Routine EEG	Routine EEG Prerequisite power
Bedside EEG	100%
SE LTEM	94%
cICU EEG	91%
Neonatal EEG	91%
SG LTEM	81%
PSG	81%
MSLT	75%
IONM	53%
SSEP	47%
BAEP	44%
PRVEP	38%
FVEP	34%
NCS	25%
EMG	3%

Figure 4.35 is a Pareto Chart illustrating modality rank relationships with routine EEG as a prerequisite to learning.

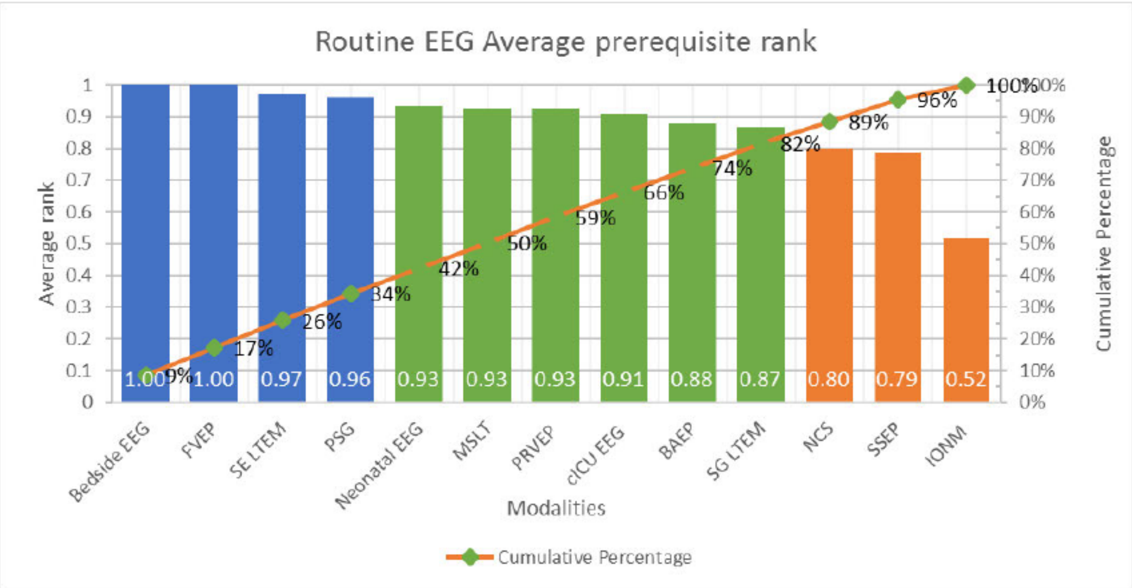


Figure 4.35: Routine EEG average prerequisite rank

Routine EEG holds a high prerequisite rank with all modalities and only NCS, SSEP, and IONM did not have at least a prerequisite rank relationship above the 25th percentile.

4.11.1.1.2 Neonatal EEG

Table 4.12 summarises the 86 selections made for neonatal EEG. Neonatal EEG was indicated as dependent on prior knowledge of other modalities 53 times and selected as prerequisite to learning 33 times.

Table 4.12: Neonatal EEG modality relationships

Modality relationship to Neonatal EEG	Count	Neonatal EEG Prerequisite frequency	Neonatal EEG Dependence frequency
Routine	27	1	26
Bedside EEG	23	1	22
SE LTEM	11	9	2
SG LTEM	11	11	0
cICU EEG	10	8	2
IONM	2	2	0
PSG	2	1	1
Total	86	33	53

Neonatal EEG dependency on prior learning is summarised in Table 4.13.

The only modalities neonatal EEG was found significantly dependent on were routine EEG (81%) and bedside EEG (69%). The average rank of dependency to routine EEG was 0.26 and to bedside EEG was 0.46.

Table 4.13: Neonatal EEG dependency power

Modality relationship to Neonatal EEG	Relationship Power	Neonatal EEG Dependence power
Routine EEG	84%	81%
Bedside EEG	72%	69%
cICU EEG	31%	6%
SE LTEM	34%	6%

Neonatal EEG prerequisite modality relationships are summarised in Table 4.14. Neonatal EEG had a prerequisite power relationship with only the three long-term monitoring modalities, SG LTEM, SE LTEM, and cICU EEG.

Table 4.14: Neonatal EEG prerequisite power

Modality relationship to Neonatal EEG	Relationship Power	Neonatal EEG Prerequisite power
SG LTEM	34%	34%
SE LTEM	34%	28%
cICU EEG	31%	25%

The prerequisite rank importance of Neonatal EEG for long-term monitoring is shown in Figure 4.36.

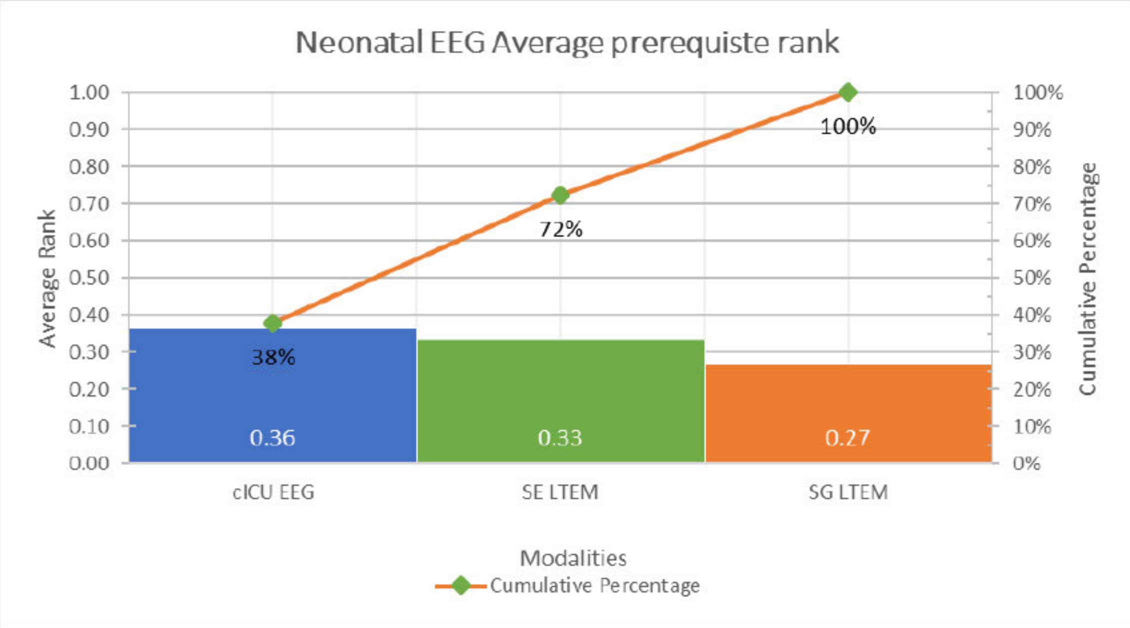


Figure 4.36: Neonatal EEG average prerequisite rank

4.11.1.1.3 Bedside EEG

Bedside EEG was selected 172 times (Table 4.15). Bedside EEG was indicated as dependent on prior knowledge of related modalities 33 times and selected as prerequisite for learning 139 times. Bedside EEG was indicated as most dependent on prior knowledge of routine EEG (n = 29 – dependence power 91%).

Table 4.15: Bedside EEG modality relationships

Modality relationship to Bedside EEG	Count	Bedside EEG Prerequisite frequency	Bedside Dependence frequency
IONM	25	25	0
SSEP	12	10	2
Routine	8	1	7
Bedside EEG	4	1	3
FVEP	4	3	1
NCS	4	0	4
PRVEP	4	2	2
SG LTEM	2	2	0
EMG	2	2	2
PSG	2	2	0

Bedside EEG as prerequired knowledge is summarised in Table 4.16. Bedside EEG was indicated as being essential prerequisite knowledge to learning neonatal EEG, cICU EEG, and SE LTEM.

Table 4.16: Bedside EEG prerequisite power

Modality relationship to Bedside EEG	Relationship power	Bedside EEG Prerequisite power
Neonatal EEG	81%	78%
cICU EEG	78%	78%
SE LTEM	75%	75%
SG LTEM	66%	66%
PSG	38%	34%
IONM	25%	25%

The prerequisite rank importance of Bedside EEG is shown in Figure 4.37.

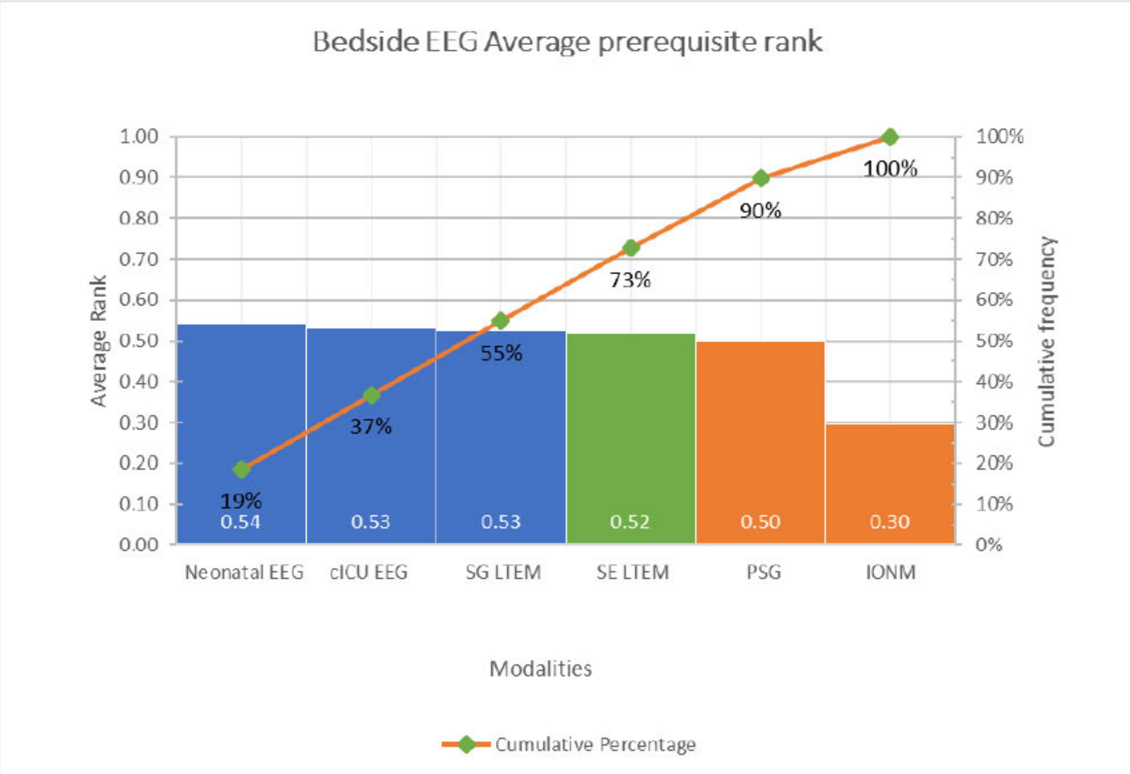


Figure 4.37: Bedside EEG average prerequisite rank

4.11.1.2 Evoked potential modalities

4.11.1.2.1 Brainstem auditory evoked potential

Brainstem auditory evoked potential was selected 67 times (Table 4.17) and was indicated as dependent on prior knowledge of related modalities 19 times. It was selected as prerequisite for learning 48 times. The BAEP modality was indicated as the most important prerequisite to learning IONM (n = 25 – prerequisite power 78%).

Table 4.17: BAEP modality relationships

Modality relationship to BAEP	Count	BAEP Prerequisite frequency	BAEP Dependence frequency
Bedside EEG	4	1	3
EMG	4	3	1
FVEP	25	25	0
MSLT	2	2	0
Neonatal EEG	2	2	0
PSG	4	0	4
Routine EEG	4	2	2
SE LTEM	2	2	0
SG LTEM	8	1	7
SSEP	12	10	2
Total	67	48	19

Table 4.18 shows the relationship power of BAEP as either prerequisite for, or dependent on, related modalities. BAEP had no greater than $\geq$ 25% dependence for learning on any modality. BAEP is most dependent on Routine EEG with a power of 22%.

The BAEP modality showed a $\geq$ 25% prerequisite power to only two modalities. These were IONM with an essential relationship (78%) and an average rank of 0.25, and SSEP that showed only a 31% tertiary relationship with an average rank of 0.33.

Table 4.18: BAEP modality relationship power

Modality relationship to BAEP	Relationship power	BAEP Prerequisite power	BAEP Dependence power
IONM	78%	78%	0%
Routine EEG	25%	3%	22%
SSEP	38%	31%	6%

4.11.1.2.2 Somatosensory evoked potential

Somatosensory evoked potential was selected 88 times (

Table 4.19). The SSEP modality was indicated as dependent on prior knowledge of related modalities 42 times and selected as prerequisite for learning related modalities 46 times.

Table 4.19: SSEP modality relationships

Modality relationship to SSEP	Count	SSEP Prerequisite frequency	SSEP Dependence frequency
Bedside EEG	1	0	1
BAEP	10	2	8
cICU EEG	0	0	0
FVEP	6	5	1
IONM	29	29	0
SG LTEM	2	2	0
MSLT	1	0	1
EMG	5	4	1
NCS	18	0	18
PRVEP	3	3	0
PSG	3	1	2
Routine EEG	10	0	10
Total	88	46	42

Table 4.20 and Table 4.21 shows the prerequisite and dependence relationships of SSEP. Somatosensory evoked potential was considered prerequisite for IONM with an essential relationship power of 91% and a rank average prerequisite rank of 0.45.

In contrast SSEP was not found to be essentially dependent on any other modality. The only dependency relationships were with NCS (56%) and routine EEG (31%). The average rank of dependence to NCS was high at 0.75 despite the secondary relationship power. Routine EEG rank importance was low at 0.13.

Table 4.20: SSEP prerequisite power

Modality relationship to SSEP	Relationship power	Prerequisite power
IONM	91%	91%
BAEP	31%	6%
NCS	56%	0%
Routine EEG	31%	0%

Table 4.21: SSEP dependence power

Modality relationship to SSEP	Relationship power	Dependence power
IONM	71.9%	71.9%
BAEP	37.5%	6.3%
NCS	56.3%	3.1%
FVEP	25.0%	3.1%

4.11.1.2.3 Pattern reversal visual evoked potential

Pattern reversal visual evoked potential was selected 73 times (Table 4.22). The PRVEP modality was indicated as dependent on prior knowledge of related modalities 42 times and selected as prerequisite for learning related modalities 31 times.

Table 4.22: PRVEP modality relationships

Modality relationship to PRVEP	Count	PRVEP Prerequisite frequency	PRVEP Dependence frequency
Bedside EEG	2	0	2
BAEP	10	1	9
cICU EEG	0	0	0
FVEP	26	8	18
IONM	13	13	0
SE LTEM	0	0	0
SG LTEM	2	2	0
MSLT	0	0	0
EMG	2	2	0
Neonatal EEG	0	0	0
NCS	3	0	3
PSG	0	0	0
EEG	8	0	8
SSEP	7	5	2
Total	73	31	42

Table 4.23 and Table 4.24 shows the prerequisite and dependence relationships of PRVEP.

The strongest total inter-modality relationship is with FVEP at a relationship power of 81%.

Pattern reversal visual evoked potential dependence relationship with FVEP is secondary with a power of 56%, however the average rank dependence was nearly complete at 0.94 (Figure 4.38).

The only prerequisite modality relationships with PRVEP were with IONM (41%) and FVEP (25%). The PRVEP prerequisite rank to IONM was 0.23, and 0.67 to FVEP.

Table 4.23: PRVEP prerequisite power

Modality relationship to PRVEP	Relationship power	PRVEP Prerequisite power
IONM	41%	41%
FVEP	81%	25%

Table 4.24: PRVEP dependence power

Modality relationship to PRVEP	Relationship power	PRVEP Dependence power
FVEP	81%	56%
BAEP	31%	28%
Routine EEG	25%	25%

The average dependency rank importance of PRVEP is shown in Figure 4.38.

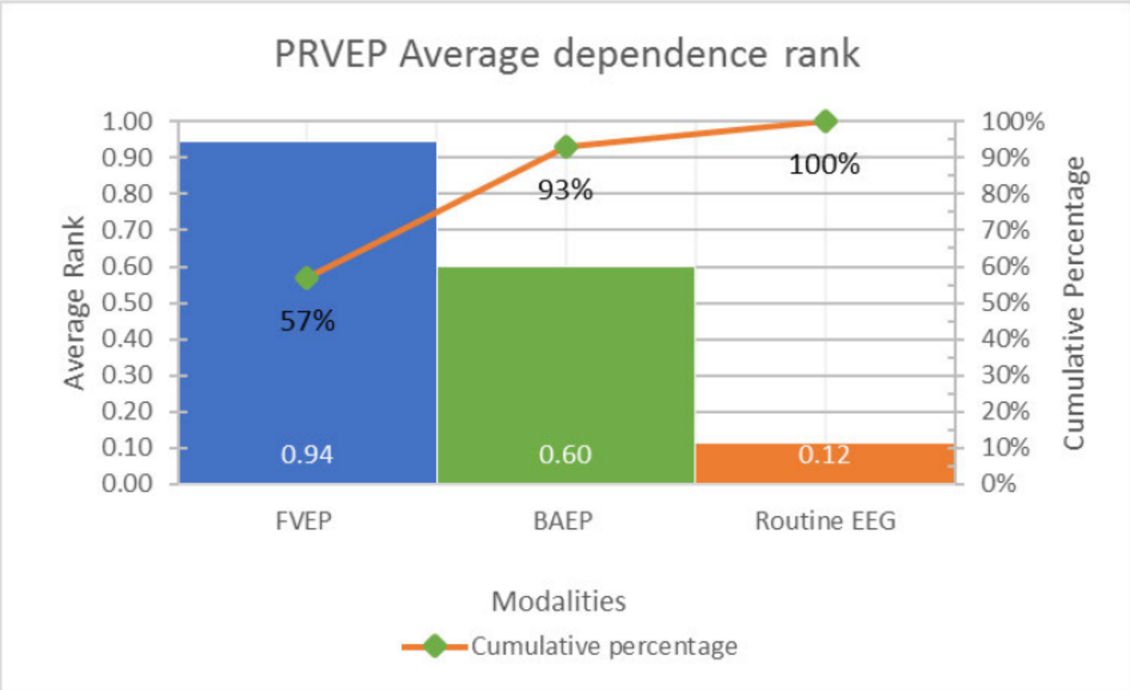


Figure 4.38: PRVEP average dependence rank

4.11.1.2.4 Flash visual evoked potential

Flash visual evoked potential was selected 78 times (Table 4.25). The FVEP modality was selected as dependent on prior knowledge of related modalities 24 times and selected as prerequisite for learning related modalities 54 times.

Table 4.25: FVEP modality relationships

Modality relationship to FVEP	Count	FVEP Prerequisite frequency	FVEP Dependence frequency
Bedside EEG	3	1	2
BAEP	8	5	3
IONM	19	19	0
SG LTEM	2	2	0
EMG	1	1	0

Modality relationship to FVEP	Count	FVEP Prerequisite frequency	FVEP Dependence frequency
NCS	2	0	2
PRVEP	27	18	9
PSG	1	1	0
Routine EEG	7	0	7
SSEP	8	7	1
Total	78	54	24

Table 4.26 and Table 4.27 shows the prerequisite and dependence inter-modality relationships of FVEP.

The strongest total inter-modality relationship is with PRVEP at a relationship power of 84%. However, the relationship power was divided between a prerequisite relationship (56%) and a dependence relationship (28%). The prerequisite average importance rank was highest at 0.67.

Flash visual evoked potential had the highest prerequisite modality relationship with IONM (59%) with a prerequisite importance rank of 0.21.

Table 4.26: FVEP prerequisite power

Modality relationship to FVEP	Relationship power	Prerequisite power
IONM	59%	59%
PRVEP	84%	56%
SSEP	25%	22%
BAEP	25%	16%

Table 4.27: FVEP dependence power

Modality relationship to FVEP	Relationship power	Dependence power
PRVEP	84%	28%
IONM	59%	0%
BAEP	25%	9%
SSEP	25%	3%

4.11.1.3 Neuromuscular modalities

4.11.1.3.1 Electromyography

Electromyography was selected 43 times (Table 4.28). The EMG modality was selected as dependent on prior knowledge of related modalities 26 times and as prerequisite for learning related modalities 17 times.

Table 4.28: EMG modality relationships

Modality relationship to EMG	Count	EMG Prerequisite frequency	EMG Dependence frequency
Prerequisite for Bedside EEG	2	0	2
Prerequisite for IONM	15	15	0
Prerequisite for SG LTEM	2	1	1
Prerequisite for NCS	21	0	21
Prerequisite for Routine EEG	1	0	1
Prerequisite for SSEP	2	1	1
Total	43	17	26

Table 4.29 and Table 4.30 shows the prerequisite and dependence inter-modality relationships of EMG.

Electromyography was selected as prerequisite only to IONM with a secondary relationship selection power of 47% and a prerequisite learning rank of 0.27.

The only modality EMG was selected as dependent on was NCS with a dependence relationship power of 66% and an average learning importance rank of 0.72.

Table 4.29: EMG prerequisite power

Modality relationships	EMG	EMG Prerequisite power
NCS	66%	0%
IONM	47%	47%

Table 4.30: EMG dependence power

Modality relationships	EMG	EMG Dependence power
NCS	66%	66%
IONM	47%	0%

4.11.1.3.2 Nerve conduction studies

Nerve conduction studies were selected 84 times (Table 4.31).

The NCS modality was selected as dependent on prior knowledge of related modalities 5 times and as prerequisite for learning additional modalities 79 times.

Table 4.31: NCS modality relationships

Modality relationship to NCS	Count	NCS Prerequisite frequency	NCS Dependence frequency
Bedside EEG	2	1	1
BAEP	6	6	0
FVEP	4	4	0
IONM	17	17	0
SG LTEM	2	2	0
EMG	28	28	0
PRVEP	3	3	0
PSG	1	1	0
Routine EEG	3	0	3
SSEP	18	17	1
Total	84	79	5

Table 4.32 summarises the prerequisite and dependence modality relationships and ranks with NCS. The NCS modality was not significantly dependent on any other modality, however prior knowledge of NCS was essential for learning EMG (88%) and of secondary importance for learning SSEP and IONM with a power of 53%.

The average importance for learning ranks were 0.96 for EMG, 0.68 for SSEP, and 0.28 for IONM.

Table 4.32: Modality relationship power and rank to NCS

Modality relationships	Total power	Prerequisite power	Dependence power	Average Prerequisite rank
EMG	88%	88%	0%	0.96
SSEP	56%	53%	3%	0.68
IONM	53%	53%	0%	0.28

4.11.1.4 Sleep modalities

4.11.1.4.1 Polysomnography

Polysomnography was selected 97 times (

Table 4.33). The PSG modality was selected as dependent on prior knowledge of related modalities 68 times and as prerequisite for learning additional modalities 29 times.

Table 4.33: PSG modality relationships

Modality relationship to PSG	Count	PSG Prerequisite frequency	PSG Dependence frequency
Bedside EEG	8	0	8
cICU EEG	3	1	2
FVEP	1	1	0
IONM	1	1	0
SE LTEM	2	1	1
SG LTEM	1	1	0
MSLT	27	21	6
Neonatal EEG	1	1	0
PRVEP	1	1	0
Routine EEG	20	0	20
SSEP	32	1	31
Total	97	**29**	**68**

Polysomnography had three inter-modality relationships of $\geq$ 25% (Table 4.34). Multiple sleep latency testing had the highest total inter-modality relationship power (84%), however the prerequisite power to MSLT was of secondary importance for learning at 66%. The average prerequisite rank importance for MSLT was 0.51.

Polysomnography showed a secondary importance for learning relationship to routine EEG (63%) and a tertiary relationship to bedside EEG (25%). The dependence rank relationships were low at 0.16 for routine EEG and 0.24 for bedside EEG.

Additionally, NIV PAP showed a 94% dependency on PSG.

Table 4.34: PSG modality relationship power

Modality relationship to PSG	Relationship power	PSG Prerequisite power	PSG Dependence power
MSLT	84%	66%	19%
Routine EEG	63%	0%	63%
Bedside EEG	25%	0%	25%

4.11.1.4.2 Multiple sleep latency test

Multiple sleep latency testing was selected 49 times (Table 4.35). The MSLT modality was selected as dependent on prior knowledge of related modalities 41 times and as prerequisite for learning related modalities eight times.

Table 4.35: MSLT modality relationships

Modality relationship to MSLT	Count	MSLT Prerequisite frequency	MSLT Dependence frequency
Prerequisite for Bedside EEG	9	0	9
Prerequisite for cICU EEG	4	2	2
Prerequisite for IONM	1	1	0
Prerequisite for EMG	1	0	1
Prerequisite for PRVEP	1	1	0
Prerequisite for PSG	16	4	12
Prerequisite for Routine EEG	16	0	16
Prerequisite for SSEP	1	0	1
Total	49	**8**	**41**

The MSLT modality had three secondary learning importance inter-modality dependence relationships of $\geq$ 25% (Table 4.36)). Polysomnography and routine EEG had the same total inter-modality relationship power (50%), however MSLT is slightly less dependent on PSG (38%). The MSLT modality showed a weak 28% dependency on prerequisite knowledge of the modality bedside EEG.

Table 4.36: MSLT modality relationship power

Modality relationship to MSLT	Relationship power	MSLT Prerequisite power	MSLT Dependence power
Routine EEG	50%	0%	50%
PSG	50%	13%	38%
Bedside EEG	28%	0%	28%

The average dependency rank importance for MSLT is illustrated in Figure 4.39 which clearly illustrates MSLTs rank dependency on PSG.

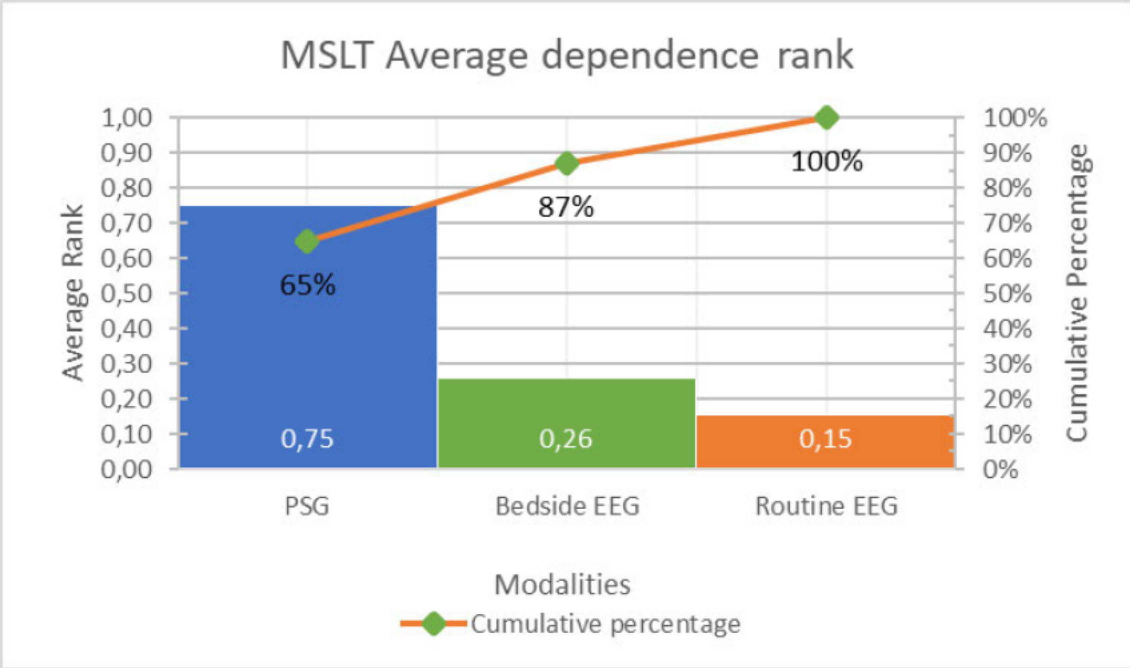


Figure 4.39: MSLT average dependence rank

4.11.1.5 Long-term monitoring modalities

4.11.1.5.1 Continuous intensive care unit electroencephalography

Continuous electroencephalography in the intensive care unit was selected 124 times (Table 4.37). The cICU EEG modality was selected as dependent on prior knowledge of related modalities 79 times and as prerequisite for learning related modalities 45 times.

Table 4.37: cICU EEG modality relationships

Modality	Count	cICU EEG Prerequisite frequency	cICU EEG Dependence frequency
Bedside EEG	27	0	27
FVEP	1	1	0
IONM	5	5	0
SE LTEM	22	8	14
SG LTEM	15	15	0
Neonatal EEG	15	9	6
NCS	2	2	0
PRVEP	1	1	0
PSG	4	2	2
Routine EEG	31	1	30
SSEP	1	1	0
Total	124	45	79

The cICU EEG modality had three tertiary importance prerequisite relationships of $\geq$ 25% (Table 4.38). Subdural grid LTEM and neonatal EEG had the same total inter-modality relationship power (47%), however cICU EEG is slightly less dependent on neonatal EEG (28%). Surface electrode LTEM showed a stronger overall relationship power, but a weak 25% prerequisite power for cICU EEG.

Table 4.38: cICU EEG prerequisite power

Modality relationship to cICU EEG	Relationship power	cICU EEG Prerequisite power
SG LTEM	47%	47%
Neonatal EEG	47%	28%
SE LTEM	69%	25%

In contrast cICU EEG had two primary dependence relationships (Table 4.39).

The total relationship power of cICU EEG to routine EEG was 97% and the dependence on prior knowledge of routine EEG was 94%.

The total relationship and dependence power with bedside EEG was 84%.

The dependence relationship with SE LTEM was stronger than the prerequisite relationship at 44%.

Table 4.39: cICU dependence power

Modality relationship to cICU EEG	Relationship power	cICU EEG Dependence power
Routine EEG	97%	94%
Bedside EEG	84%	84%
SE LTEM	69%	44%

4.11.1.5.2 Long-term electroencephalography with surface electrodes

Long-term EEG with surface electrodes was selected 130 times (Table 4.40). Long-term EEG with SE LTEM was selected as dependent on prior knowledge of related modalities 77 times and as prerequisite for learning 53 times.

Table 4.40: SE LTEM modality relationships

Modality	Count	SE LTEM Prerequisite Frequency	SE LTEM dependence frequency
Bedside EEG	26	0	26
cICU EEG	18	10	8
IONM	3	2	1
SG LTEM	25	25	0
MSLT	3	3	0
Neonatal EEG	12	2	10
NCS	2	2	0
PSG	9	8	1
Routine EEG	30	0	30
SSEP	2	1	1
Total	130	53	77

Long-term EEG with SE LTEM had two primary learning importance inter-modality dependence relationships (Table 4.41). The dependence relationship with routine EEG was 94% and with bedside EEG 81%. There were also two tertiary learning dependence relationships of 31% (neonatal EEG) and 25% (cICU EEG).

Table 4.41: SE LTEM dependence power

Modality relationship to SE LTEM	SE LTEM	SE LTEM Dependence Power
Routine EEG	94%	94%
Bedside EEG	81%	81%
Neonatal EEG	38%	31%
cICU EEG	56%	25%

The dependence vs prerequisite power relationship between cICU and SE LTEM was complicated. Looking at Table 4.42 there was a slightly higher prerequisite power to cICU EEG of 31%, however the rank dependence to cICU was 0.89 while there was no significant prerequisite rank relationship.

The only primary prerequisite power relationship was with SG LTEM at 78%.

Table 4.42: SE LTEM prerequisite power

Modality relationship to SE LTEM	SE LTEM	SE LTEM Prerequisite power
SG LTEM	78%	78%
cICU EEG	56%	31%
PSG	28%	25%

The average dependency rank importance for SE LTEM is illustrated in Figure 4.40.

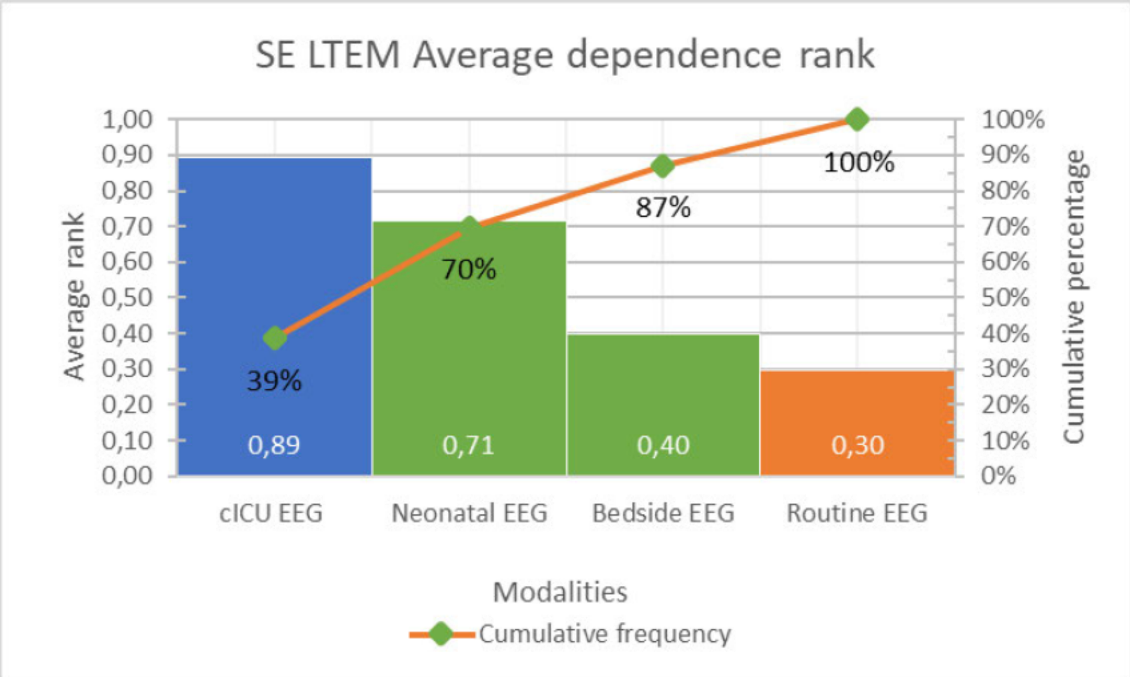


Figure 4.40: SE LTEM average dependence rank

Figure 4.41 shows the combined inter-modality learning relationship total selections per modality. This includes all selections as dependent and all selections as prerequisite for learning for any modalities. As can be seen, routine EEG showed the greatest number of intramodality relationship selections, and EMG was the most independent.

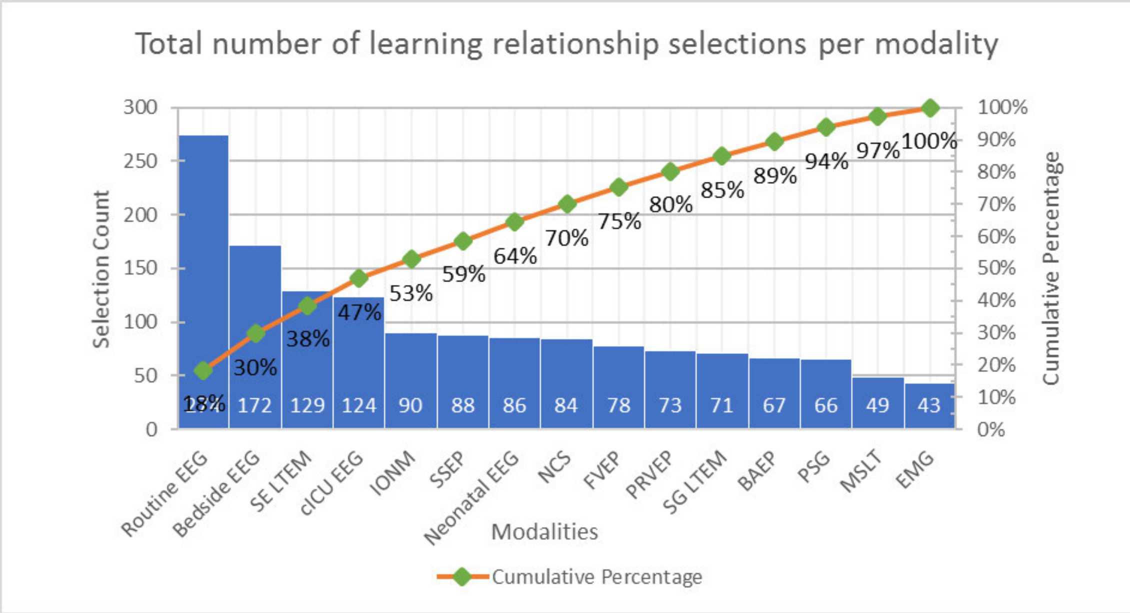


Figure 4.41: Total inter-modality learning relationship selections

Figure 4.42 shows the number of prerequisite learning selections as per modality in order of most to least prerequisite. Figure 4.43 shows the number of dependency selections per modality in order of most to least dependent on prior learning. As can be seen, routine EEG received the most selections as prerequisite for learning during WIL. Intraoperative neuromonitoring and SG LTEM received the fewest selections as prerequisite for learning. Intraoperative neuromonitoring is the most dependent on prior knowledge of other modalities, while routine EEG is completely independent. This order is in keeping with the results from Table 4.9 where routine EEG had the highest weighted rank of importance for WIL and IONM and SG EEG had a below threshold importance rank.

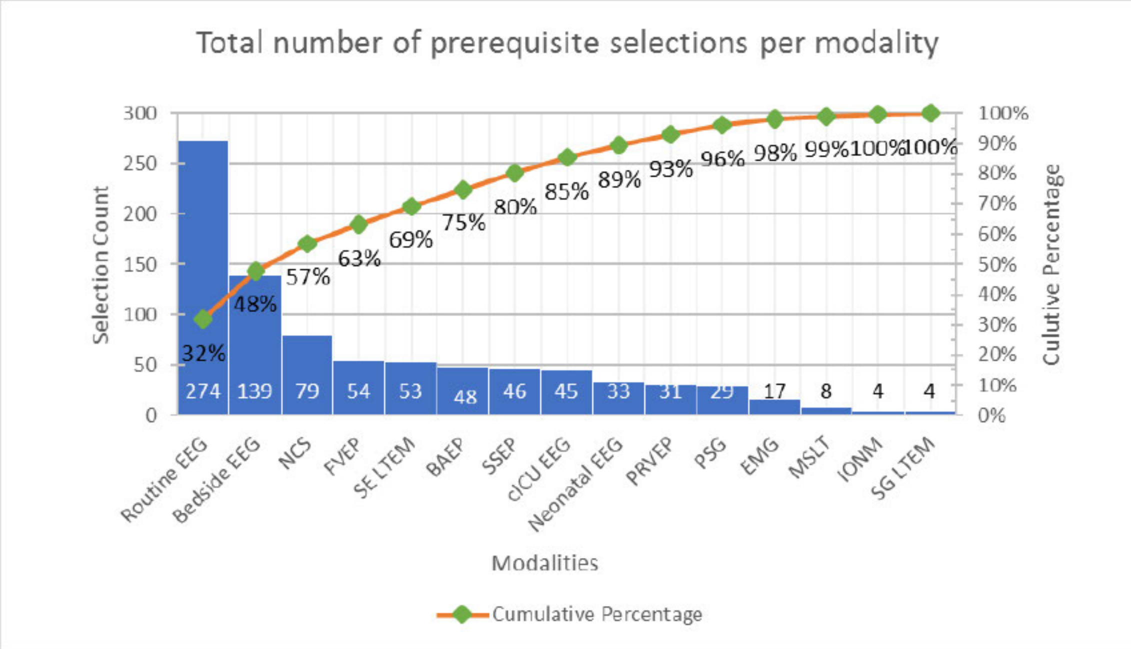


Figure 4.42: Modalities in order of prerequisite importance for learning

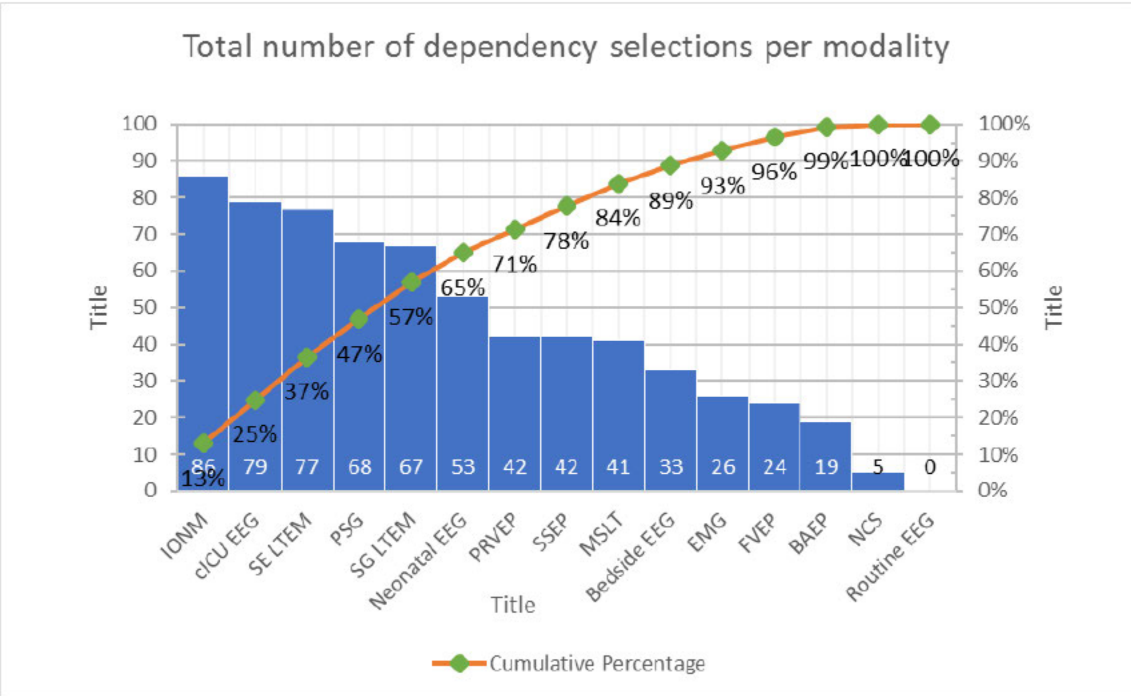


Figure 4.43: Modalities in order of dependency on prior learning

4.12 Outcome skill level selection

The OSL selections relate to aim and objective three and research question two. After determining the core BHS modalities, it is essential to also know the skills outcome level that should be achieved. Each of the test modalities that passed the inclusion threshold in Q1 were re-investigated for agreement with the Q1 outcome levels (Table 4.5). The final comparison of agreement between Q1 and Q2 is reported in Table 4.44.

Participants were presented with the skills level outcomes for each of the 16 modalities from Q1 and asked to indicate their agreement with the group majority selection or to select the final level of skill they consider that a KT-S must master by the end of their WIL in order to graduate.

4.12.1 Outcome skill level for essential electroencephalography modalities in Q2

Routine EEG, neonatal EEG, and bedside EEG all had rounded mean scores and median scores of 4 which represents a skill level of interpretative reporting.

- The modal OSL selection for routine EEG (Figure 4.44) was interpretative reporting. The PANRM was 85% (Table 4.43). The COV decreased to 0.15 (Table 4.44).
- The modal OSL selection of neonatal EEG (Figure 4.45) was interpretative reporting. The PANRM was 72%, and the PA with the median score was 80% (Table 4.43). COV decreased to 0.23 (Table 4.44)
- The modal OSL selection for bedside EEG (Figure 4.46) was interpretative reporting. The PANRM was 82% (Table 4.43). The COV decreased to 0.15 (Table 4.44).

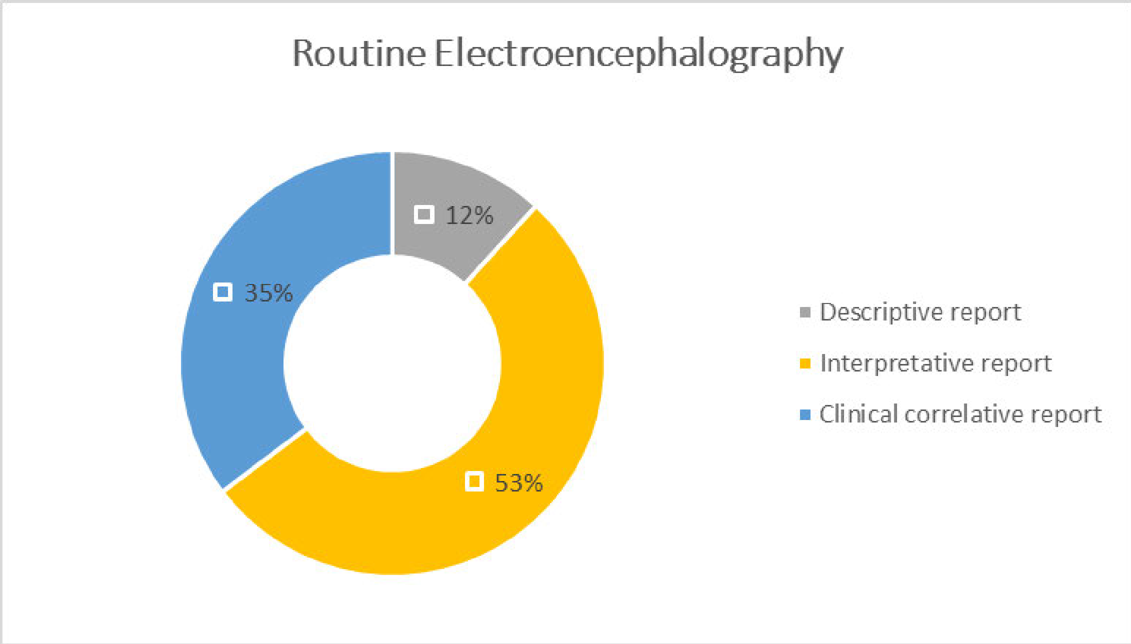


Figure 4.44: Routine EEG OSL Q2

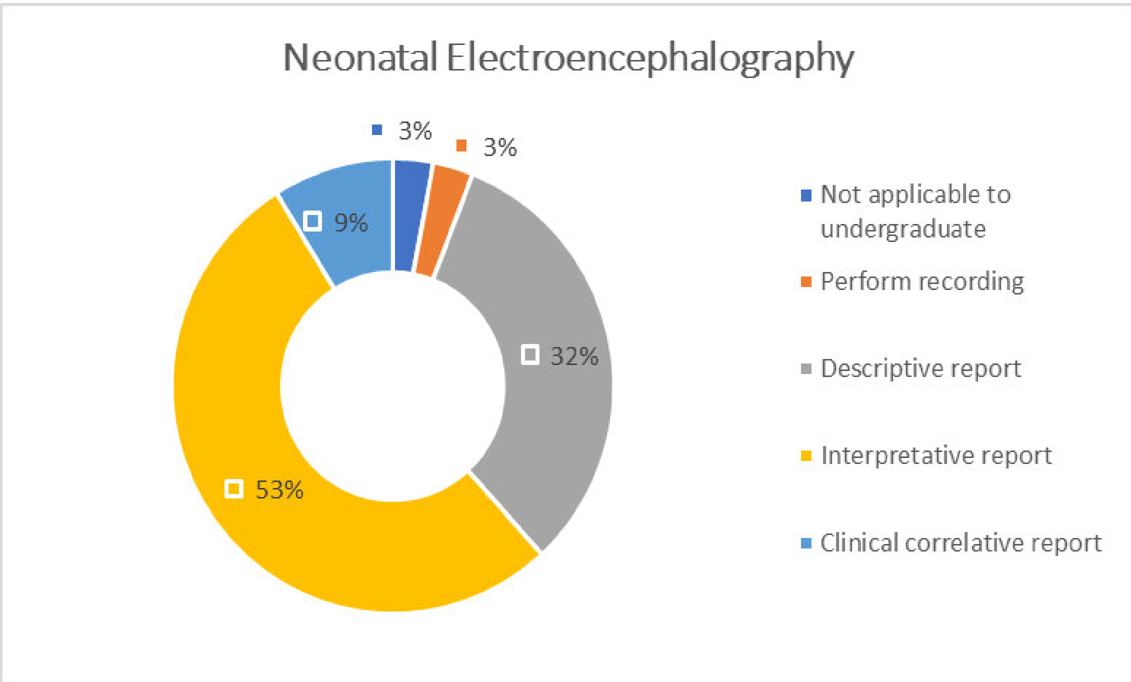


Figure 4.45: Neonatal EEG OSL Q2

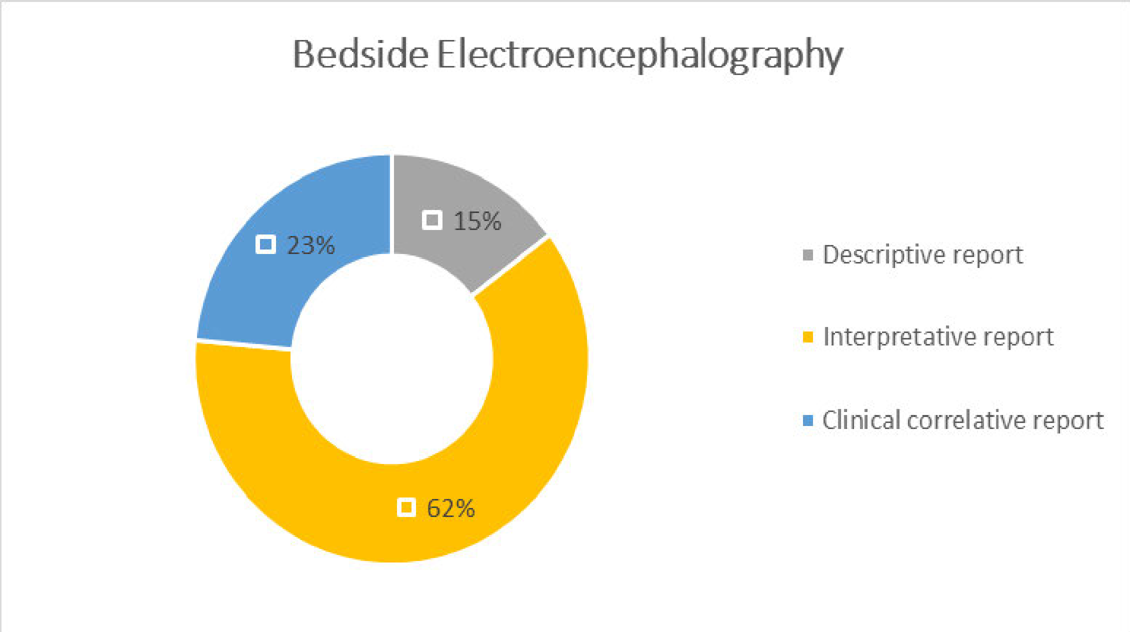


Figure 4.46: Bedside EEG OSL Q2

4.12.2 Outcome skill level for essential evoked potential modalities in Q2

Brainstem auditory evoked potential, SSEP, and PRVEP all had a rounded mean score and median score of 4 which represents a skill level of interpretative reporting.

Flash visual evoked potential: The mean rounded score was 3, equal to a skill level of technical reporting, however the median score was higher at 3.5 indicating a split between technical and interpretive reporting.

- The modal OSL selection for BAEP (Figure 4.47) was interpretative reporting. The PANRM was 76% (Table 4.43). The COV decreased to 0.23 (Table 4.44).
- The modal OSL selection for SSEP (Figure 4.48) was interpretative reporting. The PANRM was 77% (Table 4.43). The COV decreased to 0.19 (Table 4.44).
- The modal OSL selection for PRVEP (Figure 4.49) was interpretative reporting. The PANRM was 77% (Table 4.43). The COV decreased to 0.25 (Table 4.44).
- The modal OSL selection for FVEP (Figure 4.50) was interpretative reporting. The PANRM was 78% (Table 4.43). The COV decreased to 0.2 (Table 4.44).

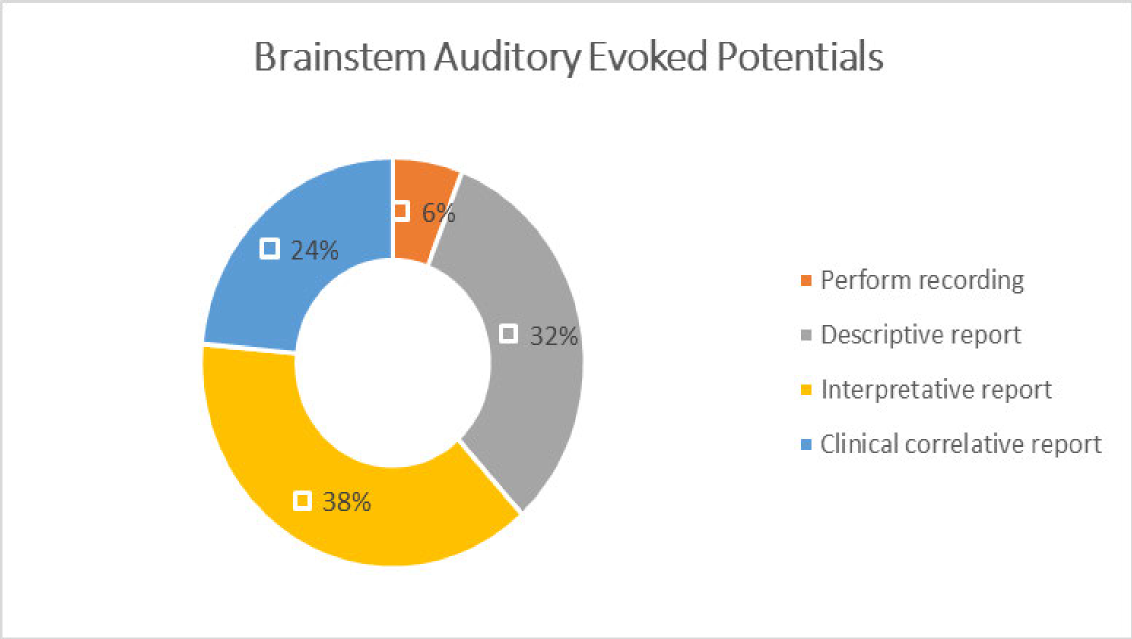


Figure 4.47: BAEP OSL Q2

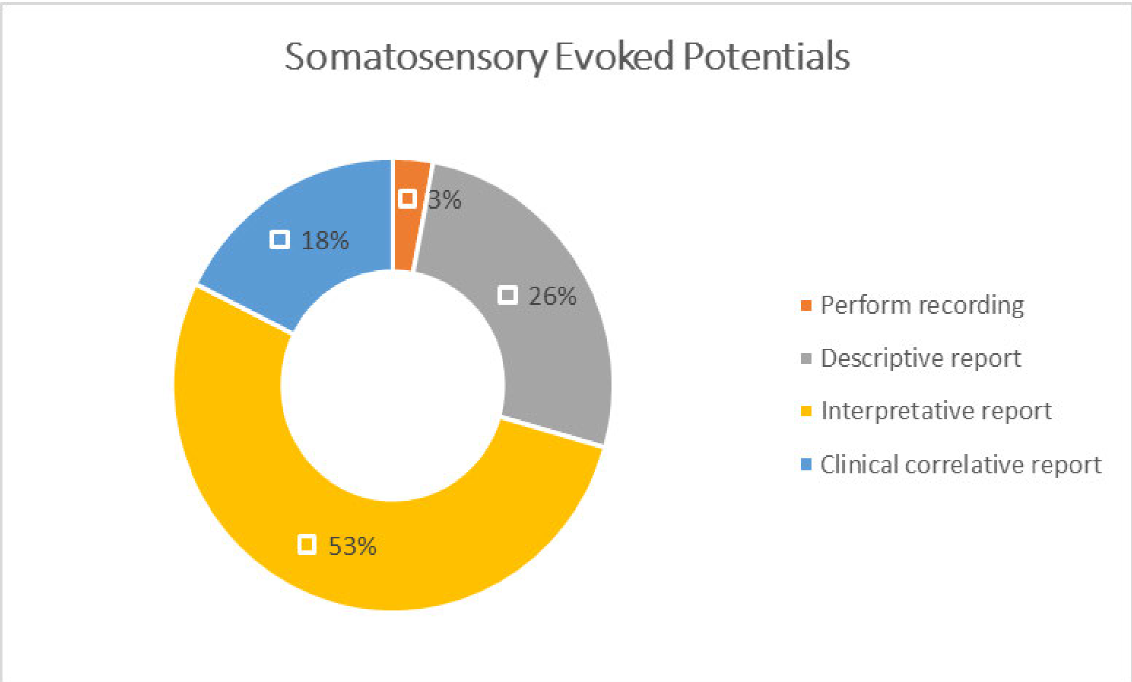


Figure 4.48: SSEP OSL Q2

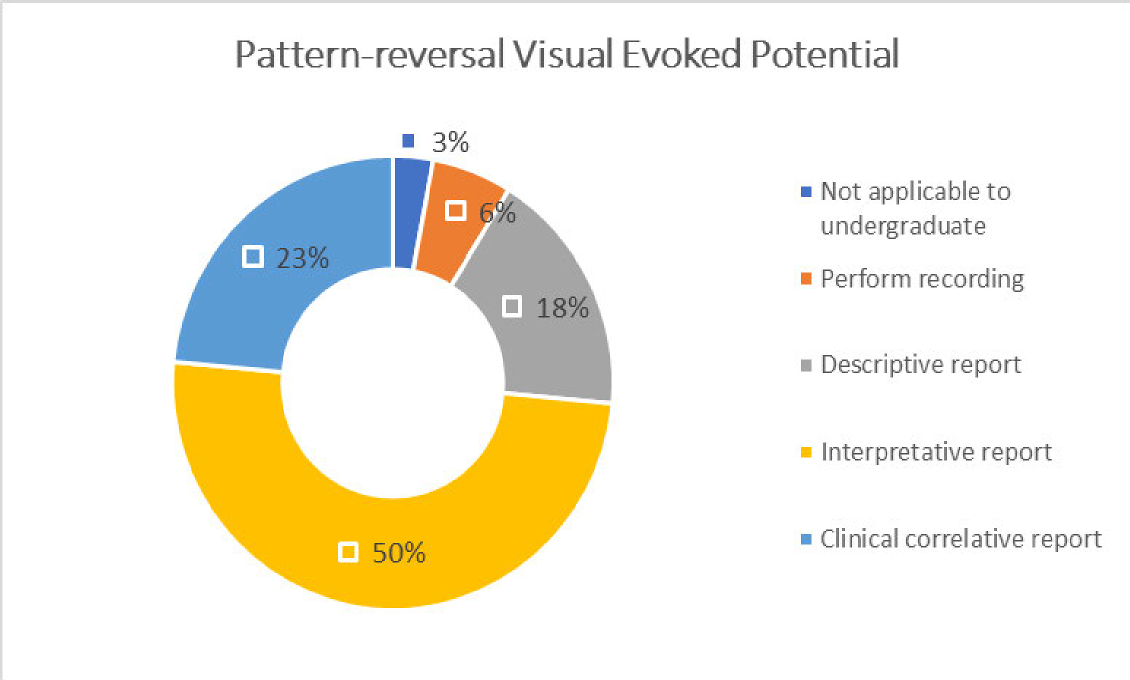


Figure 4.49: PRVEP OSL Q2

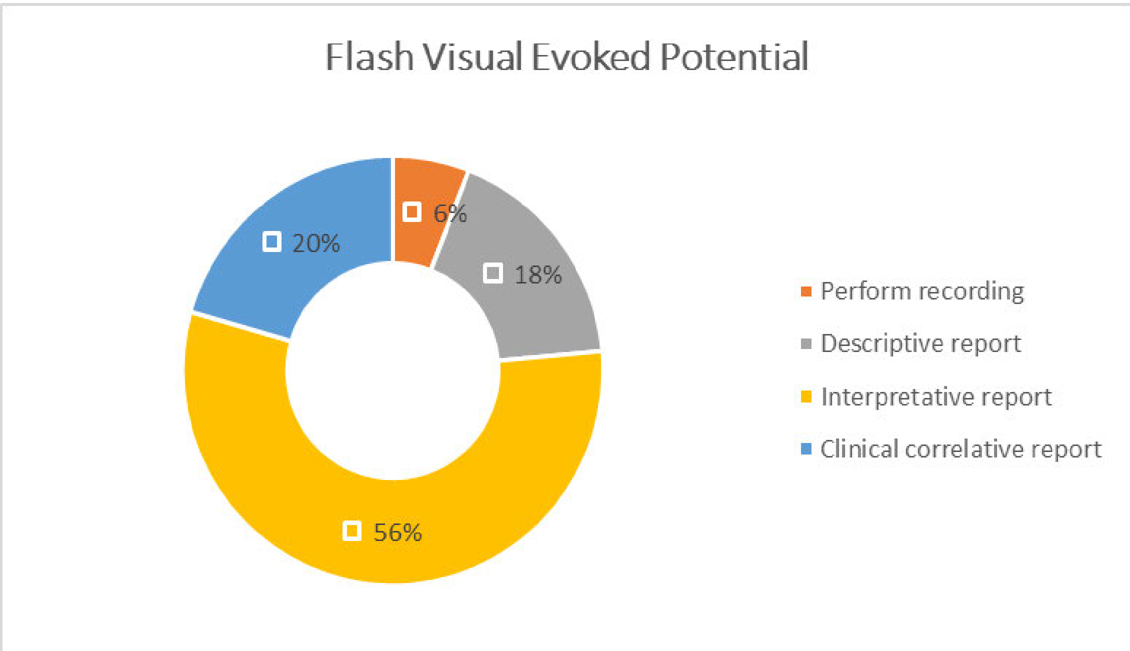


Figure 4.50: FVEP OSL Q2

4.12.3 Outcome skill level for neuromuscular modalities in Q2

Electromyography had a rounded mean score and median score of 3 which represents a skill level of descriptive reporting.

Nerve conduction studies: The mean rounded score was 3, equal to a skill level of technical reporting, however the median score was higher at 3.5 indicating a split between technical and interpretive reporting.

- The modal OSL selection indicated EMG (Figure 4.51) as not applicable to undergraduate qualification. The percentage agreement was low at 50% to the non-rounded mean score and 60% to the median score (Table 4.43). The COV decreased to 0.51 (Table 4.44). A COV > 0.5 indicates a less than reasonable internal agreement.
- The modal OSL selection for NCS (Figure 4.52) was interpretative reporting. The PANRM was 79% (Table 4.43). The COV decreased to 0.19 (Table 4.44).

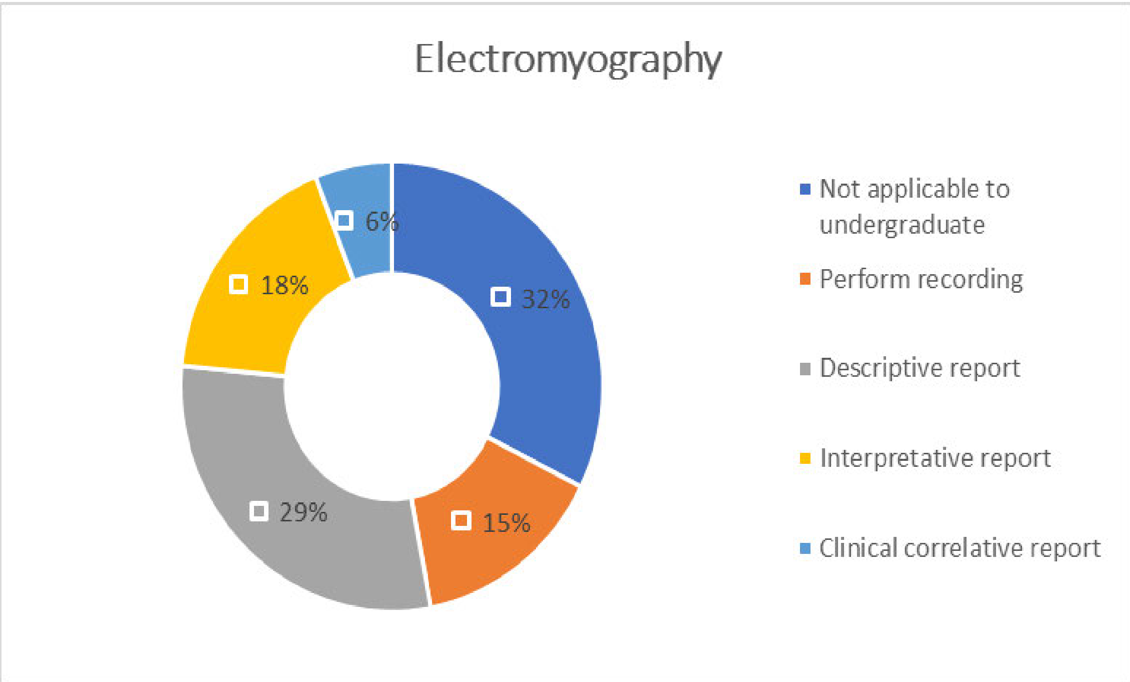


Figure 4.51: EMG OSL Q2

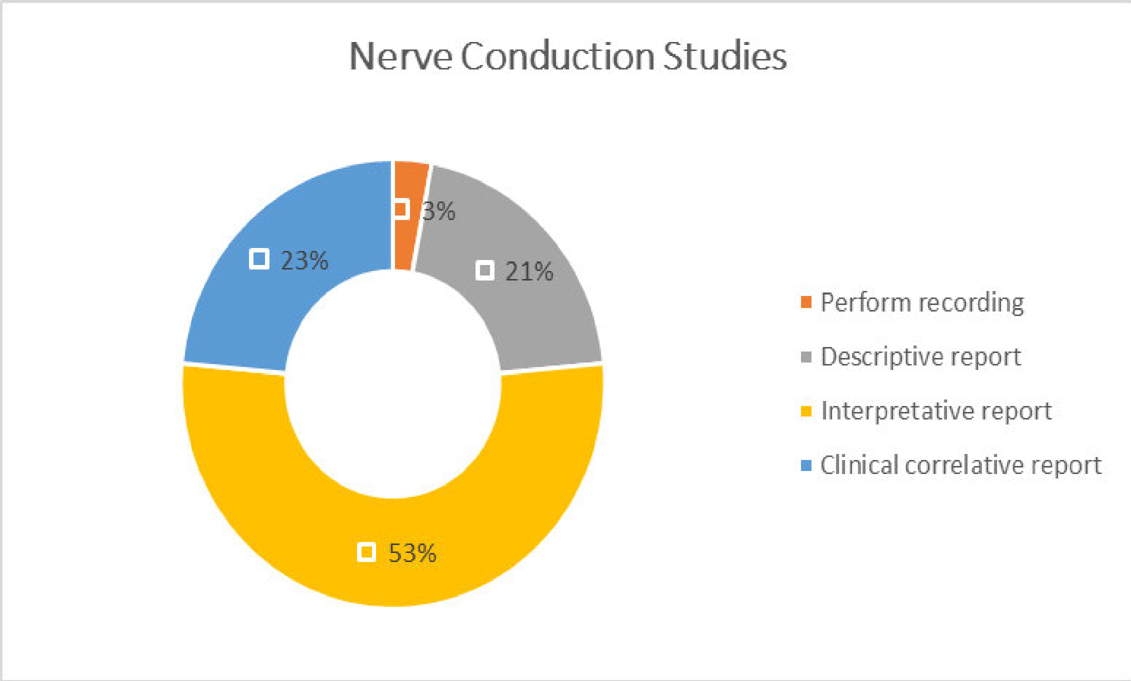


Figure 4.52: NCS OSL Q2

4.12.4 Outcome skill level for sleep modalities in Q2

Polysomnography had a rounded mean score and median score of 3 which represents a skill level of descriptive reporting.

Multiple sleep latency testing had a rounded mean score. and a median score, of 4 which represents a skill level of interpretative reporting.

- The modal OSL selection for PSG (Figure 4.53) was clinical correlative reporting. The PANRM was 85% (Table 4.43). The COV decreased to 0.2 (Table 4.44).
- The modal OSL selection for MSLT Figure 4.54 was interpretative reporting. The PANRM was 80% (Table 4.43). The COV decreased to 0.28 (Table 4.44).

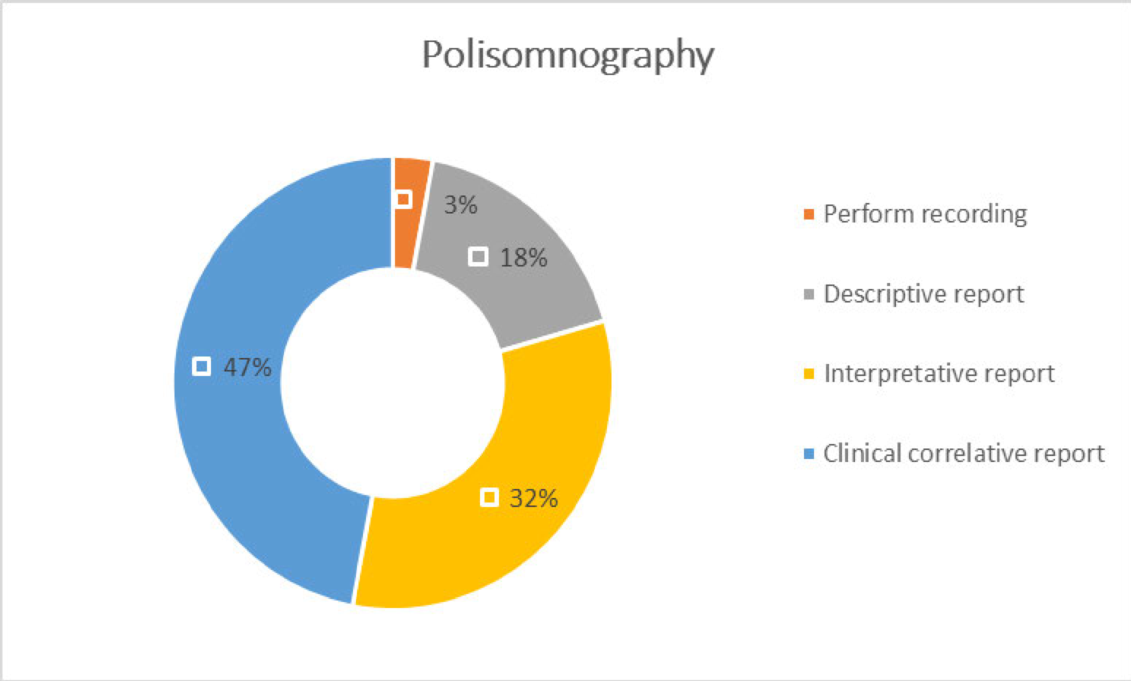


Figure 4.53: PSG OSL Q2

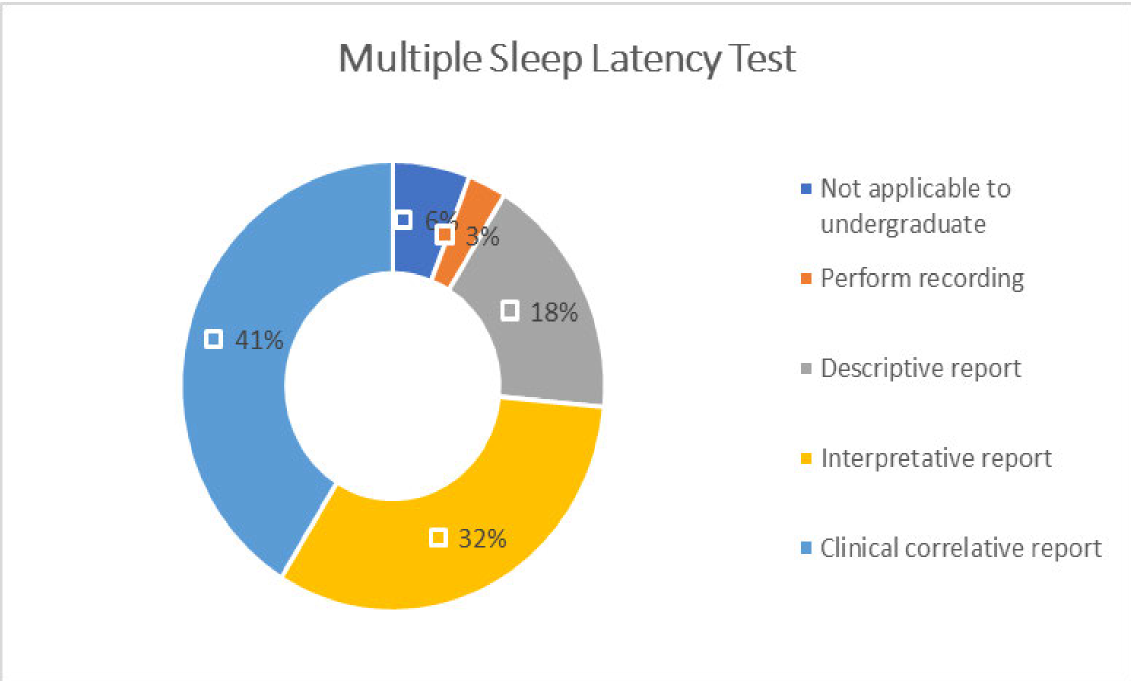


Figure 4.54: MSLT OSL Q2

4.12.5 Outcome skill level for long-term monitoring modalities in Q2

Surface electrode (SE) LTEM, cICU EEG, had mean rounded scores of 4, and median scores of 4.

- The modal OSL selection for SE LTEM (Figure 4.55) was interpretative reporting. The PANRM was 79% (Table 4.43). The COV decreased to 0.21 (Table 4.44).
- The modal OSL selection for cICU EEG (Figure 4.56) was interpretative reporting. The PANRM was 81% (Table 4.43). The COV decreased to 0.17 (Table 4.44).

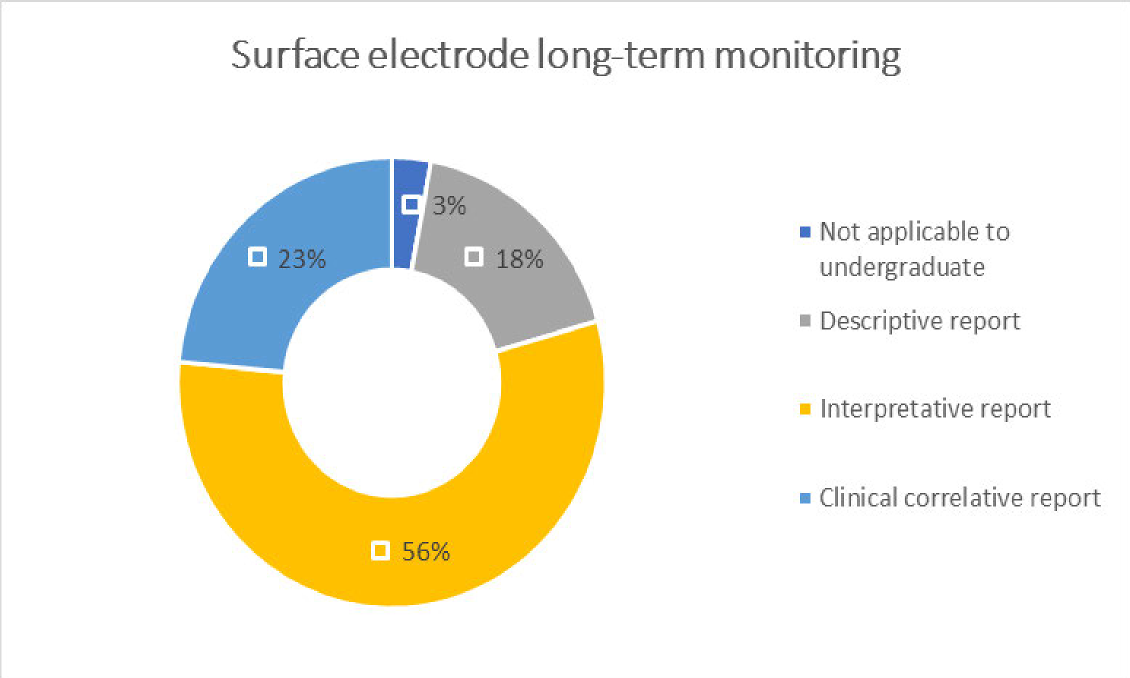


Figure 4.55: SE LTEM OSL Q2

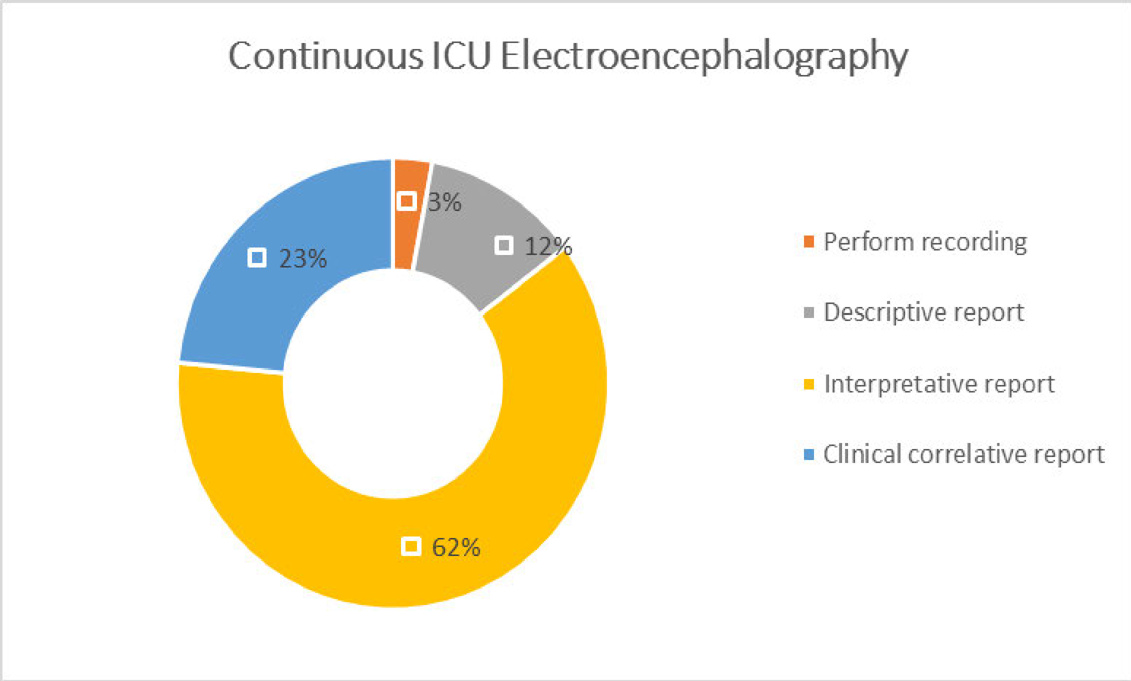


Figure 4.56: cICU EEG OSL Q2

Table 4.43: Comparison of majority skills selection, rounded mean score, and mode with percentage agreement values for Q 2

Modality	Majority outcome level	Majority Score (mode)	Mean outcome level	Mean score	SD	95% Confidence interval	PANRM	Rounded mean score	PA rounded mean	Median outcome level	Median score	PA with median	**Coefficient of variation
NCS	Interpret	4	Interpret	3,97	0,76	3.716 – 4.225	79	4	80	Interpret	4	80	0,19
PSG	Clinical	5	Interpret	4,24	0,85	3.948 – 4.523	85	4	80	Interpret	4	80	0,20
Routine EEG	Interpret	4	Interpret	4,24	0,65	4.015 – 4.455	85	4	80	Interpret	4	80	0,15
Neonatal EEG	Interpret	4	Interpret	3,62	0,82	3.343 – 3.892	72	4	80	Interpret	4	80	0,23
EMG	Not Applicable	1	Descriptive	2,50	1,29	2.068 – 2.932	50	3	60	Descriptive	3	60	0,51
MSLT	Clinical	5	Interpret	4.00	1,13	3.621 – 4.379	80	4	80	Interpret	4	80	0,28
Bedside EEG	Interpret	4	Interpret	4,09	0,62	3.879 – 4.297	82	4	80	Interpret	4	80	0,15
BAEP	Interpret	4	Interpret	3,79	0,88	3.498 – 4.090	76	4	80	Interpret	4	80	0,23
SSEP	Interpret	4	Interpret	3,85	0,74	3.603 – 4.103	77	4	80	Interpret	4	80	0,19
SE LTEM	Interpret	4	Interpret	3,97	0,83	3.690 – 4.251	79	4	80	Interpret	4	80	0,21
cICU EEG	Interpret	4	Interpret	4,06	0,69	3.826 – 4.292	82	4	80	Interpret	4	80	0,17
PRVEP	Interpret	4	Interpret	3,85	0,96	3.531 – 4.175	77	4	80	Interpret	4	80	0,25
IONM	Interpret	4	Descriptive	2,97	1,68	2.406 – 3.535	59	3	60	Descriptive	3.5	70	0,57
SG LTEM	Interpret	4	Descriptive	2,85	1,35	2.399 – 3.307	57	3	60	Descriptive	3	60	0,47
FVEP	Interpret	4	Interpret	3,91	0,79	3.645 – 4.178	78	4	80	Interpret	4	80	0,20

Abbreviations: BAEP – brainstem auditory evoked potential; EEG – electroencephalogram; cICU EEG – continuous ICU EEG; FVEP – flash visual evoked potential; IONM – intraoperative neuromonitoring; SG LTEM – long-term EEG monitoring with subdural grid electrodes; SE LTEM – LTEM using surface electrodes only; MSLT – multiple sleep latency test; EMG – electromyography; NCS – nerve conduction studies; SSEP – somatosensory evoked potential; NIV PAP – non-invasive ventilation positive airway pressure.

** Coefficient of variation of the mean (COV) of $\leq$0.5 indicates reasonable internal agreement (von der Gracht 2012).

- Red text indicates values where no consensus measures were met, or internal disagreement was found.

4.13 Outcome skills level consensus in Q1 and Q2

Table 4.44 summarises the outcome skills levels per modality as calculated using the rounded mean. Consensus is measured using PA to the mean score. Consensus agreement between Q1 and Q2 is evaluated using the COV. A decrease in COV indicates convergence of opinion and increased consensus (Dajani, Sincoff and Talley 1979).

Twelve of the 15 (80%) independent modalities from Q1 showed outcome level consensus at the end of Q2.

Table 4.44: Outcome skills level consensus in Q1 and Q2

Modality	Q1 Mean	% Agreement	**COV	Mean Outcome level Q1	Q2 Mean	% Agreement	Mean Outcome level Q2	**COV	Increased Consensus
NCS	4	80	0.35	Interpret	4	80	Interpret	0.19	Y
PSG	4	80	0.28	Interpret	4	80	Interpret	0.20	Y
Routine EEG	4	80	0.31	Interpret	4	80	Interpret	0.15	Y
Neonatal EEG	4	75	0.30	Interpret	4	80	Interpret	0.23	Y
EMG	3	50	0.71	Analyse	3	60	Descriptive	0.51	Y
MSLT	4	80	0.30	Interpret	4	80	Interpret	0.28	Y
Bedside EEG	4	80	0.25	Interpret	4	80	Interpret	0.15	Y
BAEP	4	80	0.30	Interpret	4	80	Interpret	0.23	Y
SSEP	4	80	0.33	Interpret	4	80	Interpret	0.19	Y
SE LTEM	4	80	0.30	Interpret	4	80	Interpret	0.21	Y
cICU EEG	4	80	0.37	Interpret	4	80	Interpret	0.17	Y
PRVEP	4	80	0.32	Interpret	4	80	Interpret	0.25	Y
IONM	6	75	0.36	Analyse	3	60	Descriptive	0.57	N
SG LTEM	4	80	0.39	Interpret	3	60	Descriptive	0.47	N
FVEP	3	60	0.34	Interpret	4	80	Interpret	0.20	Y

** Coefficient of variation of the mean (COV) of < 0.5 indicates reasonable internal agreement (von der Gracht 2012).

• Red text indicates values where no consensus measures were met, or internal disagreement was found.

The only modalities that did not show increased consensus were SG LTEM and IONM. Both showed a decreased agreement with the rounded mean and increased COV indicating increased dissensus. EMG did move toward consensus with a decrease in the COV, however the PANRM still did not meet threshold for consensus on OSL despite increasing consensus. All three of these modalities are to some extent invasive.

The increased consensus COV of EMG interestingly showed a greater agreement towards a higher outcome skill level of descriptive reporting rather than only analysis of results.

These results would then be consistent with increased dissensus on inclusion of SG LTEM and IONM as an undergraduate core modality.

4.14 Outcome year for achievement of requisite skills

Determining at which year end-point either basic competency or advanced proficiency (see Section 3.13.3.2), and therefore graduate OSL, should be attained, addresses aim and objective three and four and research question three.

Table 4.45 summarises the results of these selections and shows agreement on 10 of 13 final essential modalities for achievement of basic competency at end of third year (first year of WIL). This is a 77% participant group aggregate agreement. No modalities required advanced proficiency at the end of third year. Routine EEG did not have a $\geq$ 75% agreement on final proficiency outcome year as 30% of participants indicated this should be a third-year outcome. There is however 97% agreement on competency at the end of third year and a greater than two-thirds majority indication of complete proficiency in Routine EEG at the end of fourth year.

The reverse was true of MSLT and SSEP, where a greater than two-thirds majority of participants expect only basic competency at the end of third year, however 88% expect full proficiency in MSLT and 97% expect full proficiency in SSEP at the end of fourth year.

The only modality that did not have agreement on any outcome year was EMG. Thirty-six percent of participants indicated that basic competency was not an applicable outcome for WIL, and this increased to 42% for full outcome proficiency.

Table 4.45: Outcome year for attaining competency and proficiency in essential modalities

Modality	Competency			Proficiency		
	NA	Third	Fourth	NA	Third	Fourth
Bedside		100%				82%
BAEP		76%				85%
cICU EEG		85%				82%
FVEP		81%				81%
SE LTEM		85%				79%
MSLT		*70%*				88%
EMG	*36%*	*36%*	*27%*	*42%*	*6%*	*52%*
Neonatal EEG		76%				85%
NCS		94%				94%
PRVEP		81%				81%
PSG		82%				91%
Routine EEG		97%			*30%*	*70%*
SSEP		*73%*				97%

• Red text indicates agreement values below the consensus threshold

4.15 Minimum procedure numbers

Table 4.46 summarises the group aggregate opinion on minimum number of procedures to attain full outcome skill proficiency. These results contribute to objective four and research question three.

Non-invasive positive airway pressure was included in these results as this is an independent PSG skill that is not always clinically indicated and requires specific exposure. As can be seen from the response mode for SG EEG and IONM, most frequently participants indicated that these are not appropriate for WIL – this is in line with the earlier results indicating that IONM and SG EEG did not meet the consensus threshold for inclusion in undergraduate WIL.

Table 4.46: Minimum procedure numbers for attainment of outcome skills

Modalities	Mean	Median	MODE
IONM	30	18	*0*
Subdural Grid LTEM	17	10	*0*
MSLT	19	13	10
Surface LTEM	74	25	20
NIV PAP	40	30	20
BAEPs	41	50	50
cICU EEG	69	50	50

Modalities	Mean	Median	MODE
FVEP	42	40	50
Neonatal EEG	58	35	50
PRVEPs	38	30	50
PSG	63	50	50
SSEPs	35	30	50
Bedside EEG	159	100	100
EMG	56	50	100
NCS	144	100	100
Routine EEG	235	200	100

4.16 Embedded skills and attributes

Participants were asked to contribute information regarding appropriate outcomes per year of WIL for essential modalities and associated requisite skills and attributes. These results relate to objective two and research question two of the study.

Skills classified according to the duties and functions of a KT/ KTG (Human 1996) were scored against each of the 13 core CN test modalities to determine where each would be best taught. Results of each of the five skills categories are tabulated at the end of this section.

4.16.1 Quality control skills

Nineteen individual quality control skills were identified during thematic analysis. As shown in Table 4.47, most quality control skills' selection frequency power showed an essential TLA relationship with most modalities and a secondary affinity with the rest of the testing modalities. Eight skills were selected as primary importance TLA skills for all testing modalities.

These were:

- Troubleshooting and correction of technical problems.
- Physiological artefact recognition/differentiation from activity of interest and correction thereof.
- Non-physiologic artefact recognition/differentiation from activity of interest and correction thereof.
- Applying protocol/minimum standards in all environments and with all patients.

- Aseptic infection control and safety.
- Electrical safety.
- Care of electrode placement sites (invasive and non-invasive).

Electromyography was the modality with the fewest primary quality control skills. An additional five quality control skills were selected as primary importance TLA skills for each of the 12 other core modalities.

These skills were:

- Troubleshooting and correction: physiologic patient related factors (example: level of consciousness and focus).
- Repeatability/reproducibility of serial tests (doing the test procedure – hook-up and acquisition – in a standardised way for comparable results between techs and labs and on different patients).
- Clean electrode sites: impedances.
- Accurate distance measurement.
- Annotations (monitor patient, recording, artefact, drugs, structural defects).
- Adjust to new research/ standards.

Skills with lower importance ratings included “ICU specific artefact”, “Replication” and “Management of sleep during the recording”.

“ICU specific artefact” was indicated as a primary importance TLA skill for four testing modalities, a secondary importance TLA skill for five, and a tertiary TLA skill for another four.

“Replication” was the most frequently indicated TLA skill of tertiary importance.

The skill of neatly setting up equipment in ICU was most frequently indicated as a TLA skill of secondary importance.

4.16.2 Analysis skills

Fourteen individual analysis skills were identified during thematic analysis. Table 4.48 summarises the selection frequency power of analysis skills as related to individual core modalities. Most skills had primary or secondary TLA affinity with the majority of core undergraduate outcome testing modalities.

Only two analysis skills were indicated as of primary importance for all core modalities.

These skills were:

- Pattern recognition: identifying normal.
- Apply anatomy.

Identification of abnormal patterns were of primary importance for 12 of the 13 core modalities. The only modality that shows a secondary importance for identifying of abnormal patterns was EMG at 74% selection rate.

These results were similar for compiling an interpretive report where EMG scored a tertiary relationship of 44% and SE LTEM showed a secondary selection frequency of 74%.

The skill of “Integration of results obtained from multiple tests” showed no primary TLA relationship to any testing modality and only one secondary TLA importance to NCS of 65%. A tertiary TLA importance was found in relation to all other modalities, except for Neonatal EEG which showed no significant relationship to this skill.

Correlation of video recording and identifying of sleep features was nonrelated to TLA of six test modalities. Modalities that showed a secondary or tertiary relationship included the EEG and sleep modalities.

4.16.3 Performance skills

Performance skills are practical and theoretical skills required to perform the function and duties of a CNP. Twenty-four performance skills were identified during thematic analysis Selection frequency analysis for the modality related importance power of these skills are summarised in Table 4.49. Only two skills, “Equipment machine knowledge / setting manipulation” and “Patient preparation”, had a primary importance power with all 13 core modalities.

A further five skills showed a primary importance power with all modalities except for EMG.

These were:

- Equipment machine knowledge / setting manipulation (example: changing filters, programming amplifiers).
- Surface electrode placement recording (skilful application/hook-up/ accurate and technically correct).

- History/pre-test evaluation.
- Surface RECORDING techniques.
- Personal positioning: (comfortable and stable).

The four skills dealing with needle electrode placement and techniques for recording and stimulation were found to be significantly related only to EMG. A secondary or tertiary relationship power was found. Needle placement for recording showed the highest power at 55%.

Surface electrode stimulation techniques showed a primary importance power with the SSEP and NCS modalities and a secondary or tertiary power with all other modalities.

Management of SpO_2 and intubation showed only a tertiary importance for PSG. No importance to any of the long-term or standard recording EEG modalities were found.

Continuous EEG recording in ICU (cICU EEG) was the only modality with a primary TLA importance power for the skills “Manage patient events/emergencies” and “Manage side effects to testing or treatment” and cICU EEG showed a secondary importance power for management of side-effects.

Management of patient events was only shown to have a primary importance power for bedside EEG, routine EEG, and cICU EEG. Only cICU EEG and SE EEG received a primary importance rating with bedside EEG being scored as a secondary importance skill. Both sleep modalities and neonatal and routine EEG scored a tertiary importance rating for this performance skill.

4.16.4 Communication Skills

Table 4.50 summarises the selection frequency and relationship power analysis for modality related importance of communication skills. This analysis shows the power relationship of these skills as they relate to each individual CN testing modality.

Seven of the twelve communication skills showed primary importance relationship power with all core CN modalities.

These were:

- Bedside manner: patient interaction/communication.
- Obtain cooperation / all ages / explain procedure.
- Calibration and maintenance and testing of equipment.

- Self-development – stay up to date with developments.
- Data collection and management.
- Room preparation / plan ahead.
- Maintain records / documentation of procedures.

The only modality that did not reach primary importance power with “Communicate staff Drs, nurses, and colleagues” was EMG that showed a secondary relationship power.

Flash VEP and EMG were the only two core modalities that did not show primary importance relationship power with “Protocol and procedure development”.

Working with theatre staff showed the least number of related modalities (routine EEG, SSEP, and SE LTEM) and reached only a tertiary importance level.

Communication with ICU staff was the second least important communication skill. Only bedside EEG and cICU EEG achieved a primary importance power, while neonatal EEG showed a secondary relationship with this communication skill.

4.16.5 Personal attributes

The prerequisite personal attributes our graduates must possess to integrate into private practice are summarised in Table 4.51. These results relate to aim and objective two and research question two (Table 1.1).

Twelve of the 18 personal attributes were indicated as of primary importance for all core modalities.

These were:

- Teamwork.
- Professionalism / work ethic.
- Enthusiasm.
- Be receptive.
- Critical thinking.
- Adaptability.
- Be focused, time management / organised method.
- Perform under pressure.
- Recognise personal limits and obtain assistance.

- Listening.
- Confidence without arrogance.
- Stay calm.

Electromyography (EMG) showed the highest number of non-primary importance personal attributes.

These are:

- Handle difficult patient.
- Ability to concentrate for long periods of time.
- Experiencing the test procedure to understand patient experience.
- Work with different age groups.
- Work with different personalities (patients and colleagues).

Understanding the patient experience by undergoing the procedure had the least number of primary importance relationships.

Dexterity or fine motor control was selected as primary importance for all modalities except PRVEP. However, a secondary importance relationship power of 74% was indicated.

Table 4.47: Selection frequency of quality control skills

Quality control	Bedside EEG	BAEP	cICU EEG	FVEP	PRVEP	MSLT	EMG	Neonatal EEG	PSG	Routine EEG	SSEP	SE LTEM	NCS
Troubleshooting and correction: technical problems (example: equipment position, hardware and software)	97%	94%	100%	94%	100%	100%	85%	100%	97%	97%	97%	100%	100%
Troubleshooting and correction: physiologic patient related factors (example: level of consciousness and focus)	97%	88%	88%	91%	91%	88%	55%	85%	76%	97%	76%	76%	85%
Recognition and correction of ICU specific artefact	79%	62%	97%	56%	45%	33%	45%	94%	41%	71%	62%	79%	74%
Artefact recognition/differentiation from activity of interest: correction; physiologic	94%	94%	94%	94%	94%	91%	79%	100%	88%	94%	91%	94%	94%
Artefact recognition/differentiation from activity of interest: correction; non-physiologic	97%	91%	94%	88%	97%	94%	82%	100%	88%	97%	91%	100%	94%
Apply protocol/minimum standards in all environments and all patients	100%	94%	97%	94%	100%	100%	76%	94%	94%	97%	94%	97%	88%
Replication (averaging) of waveforms during recording of a specific test.	26%	94%	29%	100%	94%	33%	36%	30%	24%	29%	91%	29%	68%
Repeatability/Reproducibility of serial tests (doing the test procedure – hook-up and acquisition – In a standardised way for comparable results between techs and labs and on different patients)	88%	100%	88%	100%	97%	76%	67%	76%	82%	85%	97%	76%	88%
ICU: neat and out of the way set-up of equipment – work around equipment	85%	59%	97%	59%	55%	45%	58%	94%	59%	76%	62%	94%	76%
Clean electrode sites: impedances	97%	97%	100%	100%	97%	94%	48%	100%	97%	100%	94%	100%	94%
Aseptic infection control and safety	85%	85%	91%	79%	91%	91%	82%	94%	94%	94%	91%	94%	94%
Sterile infection control and safety	79%	74%	85%	76%	79%	79%	76%	85%	76%	76%	76%	76%	76%
Accurate distance measurement	97%	88%	94%	94%	91%	91%	33%	97%	82%	97%	94%	85%	97%
Measure 10-20 system electrode placement positions	97%	71%	88%	65%	73%	91%	30%	88%	85%	97%	70%	100%	24%
Annotations (monitor patient, recording, artefact, drugs, structural defects)	97%	85%	97%	79%	82%	91%	52%	100%	88%	100%	82%	97%	76%
Adjust to new research/ standards	88%	85%	85%	82%	100%	97%	72%	94%	94%	91%	91%	91%	94%
Electrical safety	97%	100%	97%	97%	100%	100%	82%	100%	97%	100%	97%	97%	100%

Quality control	Bedside EEG	BAEP	cICU EEG	FVEP	PRVEP	MSLT	EMG	Neonatal EEG	PSG	Routine EEG	SSEP	SE LTEM	NCS
Care of electrode placement site (Invasive and non-invasive)	94%	94%	100%	88%	100%	100%	76%	100%	91%	97%	97%	100%	97%
Manage/control SLEEP during recording	85%	65%	62%	47%	55%	88%	24%	73%	79%	76%	47%	65%	32%

Table 4.48: Modality related importance of analysis skills

Analysis	Bedside EEG	BAEP	cICU EEG	FVEP	PRVEP	MSLT	EMG	Neonatal EEG	PSG	Routine EEG	SSEP	SE LTEM	NCS
Pattern recognition: identifying normal	100%	97%	100%	100%	94%	85%	79%	91%	94%	91%	94%	79%	97%
Pattern recognition: identifying abnormal	88%	94%	85%	88%	94%	88%	74%	88%	88%	85%	94%	76%	88%
Recognition and measurement of wave forms/calculations	82%	91%	79%	91%	97%	79%	68%	68%	74%	74%	97%	68%	97%
Interpret/compile report: written or verbal: include recording limitations	91%	79%	85%	82%	76%	79%	44%	76%	82%	85%	79%	74%	82%
Integrate results from multiple tests (i.e.: NCS/EMG)	39%	36%	42%	42%	26%	32%	47%	24%	38%	38%	35%	35%	65%
Diagnosis / classify disease	62%	59%	59%	59%	47%	59%	38%	50%	71%	53%	47%	41%	53%
Apply anatomy	82%	82%	82%	82%	88%	82%	76%	79%	79%	85%	88%	70%	94%
Apply physiology	91%	91%	91%	88%	88%	88%	68%	74%	88%	85%	82%	74%	88%
Apply pathophysiology	82%	85%	82%	79%	88%	79%	68%	79%	82%	85%	85%	74%	88%
Understand treatment options	62%	53%	68%	47%	38%	50%	38%	41%	68%	62%	47%	53%	56%
Correlating recording with video	68%	12%	74%	12%	18%	42%	12%	45%	65%	50%	9%	79%	9%
Effect of medication Drugs	97%	59%	94%	56%	59%	85%	47%	82%	76%	82%	59%	74%	53%
Indication of drugs	65%	41%	71%	38%	44%	65%	35%	62%	62%	62%	41%	50%	47%
Identifying sleep features	97%	9%	97%	12%	24%	91%	9%	88%	94%	91%	15%	82%	15%

Table 4.49: Modality related importance of performance skills

Performance	Bedside EEG	BAEP	cICU EEG	FVEP	PRVEP	MSLT	EMG	Neonatal EEG	PSG	Routine EEG	SSEP	SE LTEM	NCS
Manage patient events/emergencies	88%	58%	76%	55%	55%	58%	48%	67%	71%	77%	65%	71%	68%
Manage side effects to testing or treatment	48%	39%	52%	42%	42%	42%	42%	42%	39%	45%	45%	42%	45%
Adjust protocol to obtain relevant information to question (example: placing additional electrodes)	94%	55%	94%	52%	73%	73%	52%	91%	75%	91%	63%	84%	78%
Equipment machine knowledge/ setting manipulation (example: changing filters, programming amplifiers)	97%	88%	97%	91%	100%	94%	82%	97%	97%	100%	97%	84%	97%
Needle electrode placement recording: (skilful application / hook-up / accurate and technically correct)	9%	9%	12%	9%	9%	9%	55%	9%	0%	0%	6%	3%	23%
Surface electrode placement recording: (skilful application / hook-up / accurate and technically correct)	97%	97%	97%	97%	97%	97%	39%	100%	100%	100%	97%	97%	97%
Needle electrode placement stimulating: (skilful application / hook-up / accurate and technically correct)	12%	12%	15%	9%	9%	6%	41%	9%	3%	3%	16%	6%	22%
Surface electrode placement stimulating: (skilful application / hook-up / accurate and technically correct)	81%	88%	81%	84%	82%	79%	39%	79%	47%	50%	84%	50%	91%
History/pre-test evaluation	94%	91%	88%	91%	88%	88%	69%	84%	91%	91%	84%	81%	94%
Choose correct stimulation choice	48%	82%	39%	79%	75%	22%	25%	34%	16%	41%	84%	22%	81%
Understand/choose/modify montages	94%	70%	91%	70%	70%	79%	45%	88%	81%	100%	78%	91%	75%
Surface RECORDING techniques	100%	97%	100%	97%	97%	94%	34%	100%	97%	100%	94%	88%	97%
Needle RECORDING techniques	3%	12%	6%	6%	9%	9%	53%	9%	0%	0%	13%	0%	19%
Surface STIMULATION techniques	36%	52%	42%	55%	56%	28%	34%	34%	26%	42%	81%	29%	100%
Needle STIMULATION techniques	6%	6%	6%	6%	6%	6%	45%	6%	0%	0%	13%	0%	19%
Patient preparation: (safe patient manipulation / correct positioning / dignity / mobility / comfort)	100%	94%	100%	94%	94%	100%	76%	100%	100%	97%	100%	97%	100%
Recognise and capture waveforms	82%	97%	76%	100%	100%	73%	70%	67%	72%	69%	100%	66%	97%
Personal positioning: (comfortable and stable)	100%	91%	97%	91%	88%	94%	70%	88%	94%	97%	97%	88%	97%
Appropriate activation procedures	100%	33%	79%	33%	45%	36%	39%	67%	34%	97%	31%	78%	28%

Performance	Bedside EEG	BAEP	cICU EEG	FVEP	PRVEP	MSLT	EMG	Neonatal EEG	PSG	Routine EEG	SSEP	SE LTEM	NCS
Work with collodion or similar	39%	36%	100%	33%	22%	75%	9%	50%	91%	25%	25%	88%	6%
Setup video recording	61%	12%	76%	12%	13%	47%	13%	50%	47%	50%	6%	84%	6%
Manage sp0₂ and intubation	21%	9%	24%	9%	9%	12%	9%	21%	28%	6%	6%	13%	6%
Ambulatory recording	70%	33%	76%	30%	25%	31%	25%	69%	59%	44%	16%	63%	31%
Assess VA (visual acuity)	15%	6%	12%	70%	79%	21%	15%	24%	22%	22%	22%	22%	15%

Table 4.50: Modality related importance of communication skills

Communication	Bedside EEG	BAEP	cICU EEG	FVEP	PRVEP	MSLT	EMG	Neonatal EEG	PSG	Routine EEG	SSEP	SE LTEM	NCS
Theatre protocols – work with theatre staff	3%	13%	3%	9%	13%	9%	13%	16%	20%	27%	27%	30%	20%
ICU protocols – work with ICU staff	78%	59%	100%	53%	41%	28%	44%	69%	45%	48%	52%	65%	65%
Communicate with hearing disability	81%	88%	66%	66%	75%	72%	63%	50%	74%	84%	74%	74%	77%
Protocol and procedure development	77%	77%	81%	74%	81%	75%	59%	81%	77%	81%	77%	77%	77%
Communicate staff Drs, nurses, and colleagues	97%	91%	97%	91%	84%	84%	72%	84%	87%	84%	84%	87%	87%
Bedside manner: patient interaction/communication	100%	94%	91%	91%	91%	91%	81%	94%	90%	87%	90%	94%	94%
Obtain cooperation / all ages / explain procedure	100%	100%	88%	97%	94%	94%	81%	78%	97%	97%	97%	94%	97%
Calibration and maintenance and testing of equipment	97%	91%	91%	91%	94%	94%	84%	97%	97%	94%	97%	90%	97%
Self-development – stay up to date with developments	94%	94%	94%	91%	94%	94%	81%	94%	90%	87%	90%	87%	84%
Data collection and management	94%	94%	94%	94%	94%	94%	81%	94%	94%	94%	90%	90%	94%
Room preparation/plan ahead	94%	94%	78%	97%	97%	97%	84%	97%	94%	97%	97%	94%	94%
Maintain records/documentation of procedures	97%	97%	97%	97%	97%	97%	88%	97%	94%	94%	94%	90%	90%

Table 4.51: Modality related importance of personal attributes and skills

Personal	Bedside EEG	BAEP	cICU EEG	FVEP	PRVEP	MSLT	EMG	Neonatal EEG	PSG	Routine EEG	SSEP	SE LTEM	NCS
Teamwork	88%	84%	94%	81%	90%	90%	81%	97%	91%	88%	88%	97%	91%
Professionalism/ work ethic	100%	100%	100%	100%	97%	97%	81%	94%	100%	100%	97%	97%	100%
Enthusiasm	94%	84%	88%	88%	94%	94%	84%	94%	97%	100%	94%	94%	97%
Handle difficult patient	100%	94%	94%	94%	90%	94%	74%	94%	91%	97%	94%	94%	97%
Be receptive	97%	97%	94%	97%	94%	94%	77%	94%	100%	100%	97%	94%	97%
Critical thinking	97%	97%	94%	94%	97%	97%	77%	97%	97%	97%	100%	97%	100%
Adaptability	100%	100%	97%	97%	100%	97%	80%	97%	100%	100%	100%	94%	97%
Ability to concentrate for long periods of time	78%	84%	91%	81%	84%	90%	65%	87%	94%	84%	91%	94%	91%
Be focused, time management / organised method	97%	94%	97%	91%	94%	94%	81%	97%	100%	97%	100%	97%	97%
Perform under pressure	91%	84%	94%	84%	87%	84%	81%	97%	94%	94%	88%	94%	97%
Steady hands / dexterous / fine motor control	84%	81%	84%	81%	74%	77%	77%	81%	81%	88%	91%	84%	97%
Recognise personal limits and obtain assistance	97%	94%	97%	94%	87%	90%	84%	94%	97%	97%	94%	90%	97%
Experiencing the test procedure to understand patient experience	84%	97%	63%	94%	90%	74%	71%	61%	84%	97%	94%	63%	100%
Listening	100%	94%	94%	91%	97%	97%	84%	94%	97%	97%	94%	97%	97%
Confidence without arrogance	100%	100%	97%	100%	97%	97%	81%	97%	100%	100%	100%	94%	100%
Work with different age groups	100%	100%	100%	97%	94%	90%	74%	84%	94%	100%	97%	97%	94%
Work with different personalities (patients and colleagues)	100%	97%	97%	97%	94%	94%	74%	87%	100%	100%	100%	97%	94%
Stay calm	97%	97%	100%	97%	90%	90%	84%	97%	100%	100%	100%	97%	100%

4.17 Embedded knowledge skills required for mastering outcomes per year of learning

A total of 74 individual embedded knowledge skills were identified as prerequisite to mastering the core outcome modalities. These were investigated for primary outcome year and outcome priority. Outcome priority was determined for the qualification and separated further into achievement year. Either third year of study or fourth year of study for both competency and proficiency.

This information contributes to answering aims and objectives two and four and research question two and three.

4.17.1 Third-year knowledge skills

The third year of study is also the first year of WIL specialisation in one of the seven CT specialist categories. This is then the foundational year for TLA in CN. Knowledge skills essential to attaining all graduate level modality practice skills that were identified for learning in third year are reported below.

All primary and secondary knowledge skills received average rankings of either eight or nine on a nine-point Likert scale. Selection power of $\geq$ 75% was classified as primary knowledge and power $\geq$ 50% but < 75% were classified as secondary importance for attainment for third year.

Table 4.52 and Table 4.53 summarise the knowledge skills selected for mastering course outcome skills in third year study. Table 4.52 lists the knowledge skills selected for primary outcomes at the end of third year.

Table 4.53 lists the knowledge skills selected as secondary learning outcomes for third year. All but one of these secondary learning outcome skills show significant ($\geq$ 25%) learning representation as tertiary fourth year skills.

4.17.1.1 Primary priority for learning in third year

The percentage agreement on knowledge skills indicated as primary learning skills for third year of study showed selection power of between 81% and 99% (Table 4.52). Twenty-four of the 26 primary skills were ranked nine on a nine-point Likert scale. The other third year knowledge skills ranked an importance of eight on the same scale. Agreement with all importance scores were all > 80%.

Four skills received some selections as N/A to undergraduate study, despite the group agreement of importance of eight or nine.

These were:

- Know differences of related modalities (example: the different evoked potential tests): 4% N/A.
- Contra-indication and side-effects of testing: 4% N/A.
- Basic life support/ Cardiopulmonary resuscitation: 4% N/A.
- Digitisation of recordings (example: analog to digital conversion): 8% N/A.

Most notably "Digitisation of recordings (example: analog to digital conversion)" received the highest N/A power of 8%.

4.17.1.2 Secondary priority for learning in third year

An additional 21 knowledge skills were indicated as essential for graduation with PA between 99% and 82%. However, there was a lesser degree of agreement on the appropriate year, third or fourth, for KT-S to master these skills. As can be seen in Table 4.53, six of these skills were selected with a 74% power for third year attainment that was just below the 75% cut-off for primary attainment priority.

Five skills received a few selections as N/A to undergraduate study, despite the group agreement of an essential importance score of nine and greater than 85% agreement.

These were:

- Scope of profession (8%). 93% agreement with a score of nine.
- Equipment hardware and software options (8%) 85% agreement with a score of nine.
- Importance GA and CA (know how to calculate) (4%) 87% agreement with a score of nine.
- Software data manipulation to assist analysis (example: use and effect of filters and display settings) (4%). 93% agreement with a score of nine.
- Indication of testing / clinical application (4%). 90% agreement with a score of nine.

Only one of these skills, "Indication of testing / clinical application", did not have significant ($\geq$ 25%) power selection as a tertiary outcome for fourth year study. This skill had a 74% selection power as a third-year outcome with an overall 90% selection power and 90% agreement with a score of nine as an essential course outcome.

Table 4.52: Primary knowledge skills for mastering for third year

	Knowledge skills	Average ranking	Percent representation 7-9	Percent agreement	Year 3 Power	Year 4 Power	N/A Power
1	Importance and methods of calibrations — equipment	9	96	96	100	0	
2	General electrophysiologic recording principles. (acquisition, averaging, display)	9	100	98	96	4	
3	Normal results (normative data)	9	100	99	96	4	
4	Aspects of history taking	9	93	96	96	4	
5	Importance of technical sufficient recording	9	100	97	96	4	
6	Causes off, and methods of elimination, of artefact/faults	9	96	98	96	4	
7	Electrical safety	9	96	97	96	4	
8	Importance and methods of calibrations – patient	9	96	95	96	4	
9	Equipment variables effect on results (technical:non-physiological)	9	97	98	93	7	
10	Electrophysiological presentation of normal physiology (normal results – patterns)	9	100	98	92	8	
11	Importance of low and equal Impedances	9	96	98	92	8	
12	Principles of measurement (example: international 10-20, queen square etc.)	9	100	99	92	8	
13	Indication and results of activation procedures/ appropriate stimulation in non-responsive	9	96	98	88	12	
14	Montages – choices, indication, effect on results etc.	9	96	96	88	13	
15	Identification of EEG frequency bands during recording	9	96	96	87	13	
16	Anatomy pertaining to modality (physical location and connection/relation of structures)	9	97	97	85	15	
17	Differential amplification	9	93	96	85	15	
18	Differentiation between physiological and artefactual electro signal recording	9	100	99	84	12	
19	Know differences of related modalities (example: the different evoked potential tests)	9	97	94	82	14	4
20	Physiology pertaining to modality (generation of activity – function of the anatomy)	9	97	97	81	19	
21	Contra-indication and side-effects of testing	9	90	92	81	15	4
22	Technical aspects in recording or stimulation	9	83	96	81	19	
23	Equipment function and set-up	9	96	97	80	20	
24	BLS/CPR	9	81	89	79	17	4

	Knowledge skills	Average ranking	Percent representation 7-9	Percent agreement	Year 3 Power	Year 4 Power	N/A Power
25	Electrode types	8	96	93	96	4	
26	Digitisation of recordings (example: analog to digital conversion)	8	75	81	88	13	8

Table 4.53: Secondary knowledge skills for mastering for third year

	Knowledge skills	Average ranking	Percent representation 7-9	Percent agreement	Year 3 Power	Year 4 Power	N/A Power
27	Identify critical abnormalities requiring immediate medical intervention (status epilepticus)	9	100	99	52	48	
28	Age related abnormalities	9	96	95	52	48	
29	Identify and measure all components of responses (example: peaks, morphology etc.)	9	96	97	58	42	
30	Scope of profession	9	93	93	54	38	8
31	Age related maturation of electrophysiology results	9	100	98	64	36	
32	Equipment hardware and software options	9	79	85	56	36	8
33	Pathophysiology and diseases/diagnosis pertaining to modality (dysfunction of anatomy being tested, including interrelated organ systems affecting anatomy under investigation)	9	97	96	67	33	
34	Importance of GA and CA (know how to calculate)	9	87	87	64	32	4
35	Clinical utility of different recording parameters – what physiology is assessed through each parameter or sensor	9	93	95	70	30	
36	Software data manipulation to assist analysis (example: use and effect of filters and display settings)	9	89	93	71	29	4
37	Patient variables effect on results (technical and physiological)	9	97	97	74	26	
38	Recording variables' effect on results	9	97	97	74	26	
39	Indication of testing / clinical application	9	90	90	74	22	4
40	Clinical presentation to expect of known pathology	8	93	92	52	48	
41	Identification of sedation and outpatient medication effect on recording	8	93	82	52	48	
42	Localisation of lesions (identify anatomical location)	8	90	92	56	44	
43	Identification of in-hospital medication effect on results	8	90	91	56	44	

	Knowledge skills	Average ranking	Percent representation 7-9	Percent agreement	Year 3 Power	Year 4 Power	N/A Power
344	Limitations of test modality – practical and medical	8	97	94	59	41	
45	Consider effect of patient's mental state	8	83	89	63	37	
46	ACNS/IFCN protocols (minimum technical requirements) for all modalities	8	97	94	74	26	
47	Adjust protocol to obtain appropriate information according to history	8	90	92	74	26	
48	Calculations of all values and parameters of stimulus, recording, and results (example: intensity, luminescence, loudness, sweep duration etc.)	8	93	93	74	26	

4.17.2 Fourth year knowledge skills

The fourth year of study is the second year of WIL specialisation in one of the seven CT specialist categories. This is then when final proficiency in all core CN modalities must be demonstrated. Teaching, learning and assessment of all knowledge skills essential to attaining all graduate level modality practice skills that were not identified for primary TLA in third year must therefore be completed in the fourth year. These skills are discussed below.

The same classification of primary, secondary, or tertiary, importance was used as with the third-year skills. Selection power of $\geq$ 75% was classified as primary knowledge, and selection power of > 50%, but < 75%, was classified as secondary importance for attainment for third year.

Table 4.54, Table 4.55, and Table 4.56 summarise the knowledge skills selected for mastering course outcome skills at the conclusion of fourth year study.

Table 4.54 lists the single knowledge skill selected for primary outcome at the end of third year. Table 4.55 lists the knowledge skills selected as secondary learning outcomes for third year. The majority of these skills have a tertiary TLA representation during third year. This would indicate learning in these skills have already started. All but one of these secondary learning outcome skills show significant ($\geq$ 25%) learning representation as a tertiary fourth year skill. Table 4.56 lists the knowledge skills selected as tertiary learning outcomes for fourth year.

Twenty-three of the 26 fourth year TLA skills scored an importance of highly important (seven) to essential (nine) average ranking on a nine-point Likert scale.

4.17.2.1 Primary priority for learning in fourth year

The only knowledge skill that showed a primary selection power for attainment for fourth year was “Give diagnosis and suggest additional investigations” (Table 4.54). The average importance rank for graduate achievement was however low at four on a nine-point Likert with only a 39% overall agreement and tertiary agreement on importance for graduation.

4.17.2.2 Secondary priority for learning in fourth year

The next set of results is summarised in Table 4.55 and reflects knowledge skills of secondary importance for mastering during fourth year of study. These skills include primary and secondary graduate outcome knowledge skills.

Of the 19 skills 12 scored primary importance for graduation and an eight or nine importance ranking on the nine-point Likert scale.

These were:

- Electrophysiological presentation of pathology (abnormal results – patterns).
- Aspects of report writing.
- AASM sleep staging and related event scoring.
- Disease specific testing protocols (examples: CIDP; optic neuritis; BRECTS).
- Pathology expected from clinical presentation.
- Scope of practice.
- Correlate abnormal electrophysiology with underlying dysfunction and cause of dysfunction.
- Correlate abnormal electrophysiology with CLINICAL presentation of patient.
- Effect of UNRELATED pathology on test results.
- Neuropharmacology.
- Psychopathology (Functional neurologic disease, Psychogenic non-epileptic seizures, malingering).
- Identify and use clinical pathology to guide recording.

All of these skills showed a tertiary importance for TLA during third year of study.

An additional five skills scored a seven on the nine-point Likert scale as highly important for graduation.

These were:

- Research (73% agreement on inclusion).
- Ethical billing (74% agreement on inclusion).
- Prognostication – clinical implications of findings (68% agreement on inclusion).
- Treatment pertaining to modality (67% agreement on inclusion).
- Electrophysiological correlation with radiography result (73% agreement on inclusion).

Of these skills only two (Treatment pertaining to modality, Electrophysiological correlation with radiography result) showed tertiary TLA representation for initiation of teaching during third year.

Knowledge regarding ICU/theatre equipment and surgical procedures showed a low Likert rating, low overall representation, and < 75% agreement for inclusion as a secondary importance skill for fourth year. Thirty-three per cent of participants indicated that knowledge of surgical procedures does not apply to undergraduate study.

4.17.2.3 Tertiary priority for learning in fourth year

Six of the 74 knowledge skills were selected as tertiary importance for learning for fourth year. All six did have a graduate outcome importance of between seven and nine on the nine-point Likert scale and five showed a ≥ 75% agreement as a highly important to essential graduate outcome.

The only skill that received both < 75% representation and < 75% agreement was knowledge of anaesthesia. All other modalities showed an equal tertiary agreement on outcome for either third or fourth year with agreement on attainment as an outcome for graduation.

The only skill that received ≥ 25% selection power as non-applicable to undergraduate study was introduction to advanced methods within modalities.

“Medical negligence” was rated a nine-point rating as essential for graduation with an 88% agreement, however this skill was considered only a tertiary importance for learning during either third or fourth year with only a tenuous 40% to 48% majority selection power as a fourth-year learning skill.

Equally knowledge of “HPCSA guideline on ethics and practice” and “Scope of practice” were selected as of tertiary importance for either third or fourth year of study with a slight majority selection toward fourth year.

Table 4.54: Primary knowledge skills for mastering for fourth year

	Knowledge skills	Average ranking	Percent representation 7-9	Percent agreement	Year 3 Power	Year 4 Power	N/A Power
49	Give diagnosis and suggest additional investigations (example: bloods and imaging)	4	20	39	19	81	

Table 4.55: Secondary knowledge skills for mastering for fourth year

	Knowledge skills	Average ranking	Percent representation 7-9	Percent agreement	Year 3 Power	Year 4 Power	N/A Power
50	Electrophysiological presentation of pathology (abnormal results – patterns)	9	97	98	30	70	
51	Aspects of report writing	9	96	94	36	60	4
52	AASM sleep staging and related event scoring	9	97	95	48	52	
53	Disease specific testing protocols (example: CIDP; optic neuritis; BRECTS)	9	86	90	44	52	4
54	Pathology expected from clinical presentation	9	83	87	44	52	4
55	Scope of practice	9	93	93	42	50	8
56	Correlate abnormal electrophysiology with underlying dysfunction and cause of dysfunction	8	86	91	26	74	
57	Correlate abnormal electrophysiology with CLINICAL presentation of patient	8	83	82	30	70	13
58	Effect of UNRELATED pathology on test results	8	70	82	25	68	7
59	Neuropharmacology	8	68	81	33	67	8
60	Psychopathology (Functional neurologic disease, Psychogenic non-epileptic seizures, malingering)	8	79	90	32	64	4
60	Identify and use clinical pathology to guide recording	8	97	94	41	59	
62	Research	7	61	73	17	72	
63	Ethical billing	7	64	74	12	61	21
64	Prognostication – clinical implication of findings	7	57	68	18	61	21
65	Treatment pertaining to modality	7	50	67	32	54	14
66	Electrophysiological correlation with radiography result	7	58	73	34	52	14

	Knowledge skills	Average ranking	Percent representation 7-9	Percent agreement	Year 3 Power	Year 4 Power	N/A Power
67	Functions and method of working of ancillary ICU/theatre equipment (bispectral index/aneurism detection/cerebral function monitor/patient safety indicators)	6	48	63	24	59	17
68	Knowledge and understanding of surgical procedures	5	34	50	9	58	33

Table 4.56: Tertiary knowledge skills for mastering for fourth year

	Knowledge skills	Average Ranking	Percent representation 7-9	Percent agreement	Year 3 Power	Year 4 Power	N/A Power
69	HPCSA guideline on ethics and practice	9	89	93	48	48	4
70	Sensitivity and specificity of testing	8	86	92	44	46	
71	Medical negligence	9	87	88	40	48	12
72	Clinical grading scales	8	72	78	40	44	16
73	Anaesthesia	7	64	72	38	45	17
74	Theory introduction on advance modalities or methods within modalities (examples: BAEP steady state/ multi-modality evoked potential IOM/ VEP sinewave grating)	7	65	75	27	46	27

4.18 Completion rate differences between questionnaires

Fifty-six percent (56%) of Q1 participants contributing to modality selections completed all questions. The low (less than 70%) completion rate was investigated and attributed to forced answer fatigue during the open-ended skills contribution questions. Validation is the term used for forced response reminders that prevent a participant from skipping a question. Strong validation settings can improve the quality of data by ensuring all questions are answered by the same number of participants. However, it can also cause participant frustration and cause abandonment of the questionnaire. After receiving feedback from participants and discussion with the QP helpdesk validation settings for Q2 were relaxed to request responses rather than force answers.

Disabling the forced validation may have contributed to the much higher Q2 completion rate (83%). The increased completion rate can however not fully be ascribed to validation settings. Firstly, this study used snowballing and secondly all potential participants that received invitations to Q1 were reinvited to participate in Q2.

Disabling of the forced answer validation feature however did lead to one participant skipping question 18 – modality raking – despite continuing to answer further questions, illustrating how this feature can assist in ensuring complete data sets.

4.19 Sample statistic comparison

Combined gender and registration status of Q1 and Q2 participants are summarised in Table 4.57. Clinical neurophysiologist population statistics for the study period are summarised in Table 4.58.

The information in Table 4.58 includes all active registrations at the end of the study period and includes an unknown number of retired first generation CNPs.

Table 4.57: Sample gender and practice status of participants during Q1 and Q2

	Supervised	%	Independent	%	Private	%	Combined Independent and Private	%	Male	%	Female	%
Q1	3	6	25	49	23	45	48	94	12	24	39	76
Q2	6	17	20	56	10	28	30	83	10	28	26	72
Total	9	10	45	52	33	38	78	90	22	25	65	75

Table 4.58: Population gender and registration demographics for study period

Neurophysiology	Gender				Population	
Registration	Female	%	Male	%	Total	%
KT	45	69	20	31	65	41
KTG	68	74	24	26	92	59
Total	113	72	44	28	157	

Source: Personal communication email 06 October 2022 Mrs Talent Hlongwane, RCT Committee Coordinator

Gender distribution in our total response sample across both questionnaires were 25% male and 75% female. The population of HPCSA registered CNPs during the study period were found to be comparable with 28% male and 72% female.

All supervised practice registrations must be from the KT group. Due to the historical inconsistencies in practice category registration after inception of the BTech qualification the KT and KTG registration categories may be represented in either the independent or private practice groups.

Table 4.59 and Table 4.60 summarise the practice category and gender distribution of the 2023 CNP population. Only one additional practitioner was registered after the study period. The KT and KTG registration distribution changed slightly with an increase in KTG registrations. The percentage supervised practice practitioners were confirmed at 8%.

Only 10% of total participants across both questionnaires reported supervised practice registration, and the gender demographics between the study sample and population distribution remained stable. The author believes the data is a good representation of the CNP population. This serves to validate the accuracy of the results of this study as representative of population opinion.

Table 4.59: 2023 Registration and practice category distribution

	Supervised	Independent	Private	Combined Private and Independent	Total Practitioners	% Supervised	% Independent	% Private	% Combined Private and Independent	Total
KT	13	11	30	41	54	24%	20%	56%	76%	34%
KTG	0	27	77	104	104	0%	26%	74%	100%	66%
Total	13	38	107	145	158	8%	24%	68%	92%	

Table 4.60: 2023 Population gender demographics

	Supervised	Independent	Private	Combined Private and Independent	Total Practitioners	% Supervised	% Independent	% Private	% Combined Private and Independent
KT Male	3	6	10	16	19	16%	32%	53%	84%
KT Female	10	5	20	25	35	29%	14%	57%	71%
KTG Male		5	20	25	25	0%	20%	80%	%
KTG Female		22	57	79	79	0%	28%	72%	100%
Total	13	38	107	145	158	8%	24%	68%	92%

Source for Table 4.59 and Table 4.60: Personal communication email 10 August 2023 Ms Veli Lukhozi, Deputy Company Secretary: Dental Therapy & Oral Hygiene, Medical Technology, Radiography and Clinical Technology

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4.20 Results conclusion

The results from the initial personal interactions and literature review were used to formulate Q1. This questionnaire comprised both closed and open-ended questions.

The yield from the Q1 started to create an impression of industry expectations of a BHS CN graduate as far as CN practice modalities were concerned. Additionally, a great number of opinions were raised regarding supportive and embedded skills and knowledge.

Questionnaire 2 worked towards both gaining insight into consensus regarding the core vs. desired modalities and understanding how learning could be structured in a supportive framework. Furthermore, Q2 clarified the modality relationships between embedded learning of practical, knowledge, and personal attribute skills.

Finally, Q2 clarified the minimum required outcome practice skills in a defined number of core modalities. These modalities were investigated in two levels of ability: basic competency and full proficiency. These desired outcome levels were then matched with required practical and theoretical skills and finally according to the desired outcome year within the undergraduate WIL period.

The effects of these results and formulation into a WIL framework will be discussed in the next chapter and the outcome of a proposed framework for the WIL period is presented in Chapter 6 as a conclusion to this research.

CHAPTER 5: DISCUSSION OF FINDINGS

5.1 Introduction

To the best knowledge of the researcher this is the first study investigating the core components of a WIL based education programme in any specialist CT category offered by South African universities of technology.

In this chapter, the relevance and implications of the results reported in Chapter 4 are discussed with consideration of how the university of technology-based CT educational offerings compare to reported industry outcome expectations.

The primary objective of the study was the development of a proposed WIL content framework and all the requisite information to achieve this was obtained. Referring to Table 1.1, the main aims of the study were determining the core of the clinical neurophysiology (CN) test modalities and related embedded prerequisite knowledge and skills required for an industry aligned undergraduate degree.

This was achieved and at the end of Q2 agreement was found for inclusion of 13 of the original 23 modalities. This represented five of the original eight modality categories, namely, electroencephalography, nerve conduction studies, evoked potentials, sleep studies, and long-term electroencephalography.

This outcome was remarkably similar to the original 1984 modality list (Appendix 9) with the exception of LTEM.

Questionnaire 2 confirmed a very high level of agreement on outcome skill levels required for private practice in these 13 core modalities. Participant agreement on outcome year for competency (end of third year) and proficiency (end of fourth year) for these modalities were equally high. Embedded practical and knowledge skills showed remarkable universal overlap between all modalities. Specifically, knowledge of anatomy and physiology relating to neurophysiology scored above 90% agreement as essential (nine on a nine-point scale) for mastering during the third year of study (Table 4.52). Knowledge of pathophysiology scored similarly high as a graduate outcome, but there were two thirds to one third division across third- or fourth-year outcomes (Table 4.53) with emphasis of learning during third year.

5.2 Reflection on using the Delphi method

During planning of this study provision was made for up to three rounds of questionnaires. According to Niederberger, Köberich and Network (2021) a high degree of agreement in medical guideline research can be considered as 75% and a high level of consensus when agreement reaches 95%. In this study both these standards were nearly universally met at the end of the second questionnaire.

By using a Delphi process, it was possible to aggregate the opinions of CNPs with private practice experience at or above a high degree of agreement regarding core modalities, embedded knowledge, and requisite skills, required for inclusion in the BHS undergraduate qualification.

The depth of information and confidence in agreement would not have been possible using a single survey. All aims of the research were achieved at the end of the second Delphi questionnaire round according to the pre-determined agreement level for consensus. This is in line with the methodological review by Spranger *et al.* (2022) and earlier guideline by McMillan, King and Tully (2016) that found most studies use two rounds of questionnaires.

5.3 Core modality dependencies, outcome year, and skill levels

The results reported in Chapter 4 were used by the researcher to design an affinity diagram illustrating inter-modality learning dependency relationships.

During study planning it was anticipated that multiple diagrams would be needed and that separate diagrams would be used for the third- and fourth-year study periods.

Outcome year analysis for mastering competency and proficiency of modalities indicated competency in the third year and proficiency in the fourth year for nearly all modalities (Table 4.45) and only one diagram was constructed and is included below (Figure 5.1).

Of the modalities that did not follow this pattern, EEG showed a nearly perfect competency requirement for third year. The higher outcome level of proficiency was split with one-third of participants indicating that proficiency should be reached in third year already. This supports the foundational nature of this modality to CN practice and learning. Required outcome proficiency levels were consistent with “Interpretative reporting” for all core modalities except EMG which require a level of “Descriptive reporting”.

Despite a high participant selection frequency during Q1, EMG was the modality of lowest TLA importance during Q2 analysis (Table 4.9). No consensus was found regarding the appropriate time to achieve competency and a tentative 52% majority indicated proficiency should be achieved at the end of the study period.

5.4 Reflection on selection of core outcome modalities

Seven of the eight modalities that failed to reach the Q1 selection frequency threshold did receive some selections and will be discussed. WADA testing was the only modality that received no selections.

5.4.1 Drug administration and management of adverse effects

Although this fell away as an independent modality, analysis of the qualitative skills contribution data revealed drug effects and indications as a recurrent embedded knowledge skill theme presented under multiple modalities. A similar finding was made regarding management of side-effects which was contributed as a practical skill by several Q1 participants in relation to multiple modalities.

During Q2 skills evaluation neuropharmacology received a score of eight on the nine-point Likert scale with a very high level of agreement. A two-thirds majority indicated this knowledge skill as a final year outcome; however, the one-third representation during third year supports the notion that learning should already start in the third year (Table 4.55). Knowledge of drug indication and effects and treatment options were represented as graduate skills and as modality related embedded knowledge.

This result supports the relevance of the current BHS pharmacology module offerings.

5.4.2 Transcranial Doppler

Transcranial doppler is a non-invasive modality that evaluates blood flow velocity within the intracranial cerebral arteries to monitor cerebral hemodynamic changes. The modality is used for diagnosis and monitoring of raised intracranial pressure and cerebral artery vasospasm, diagnosis of sickle cell anaemia, and determination of brain death (Edmonds *et al.* 2011). In the South African context, it is highly valuable in evaluation of and prognostication of traumatic brain injury and is most often used at the researcher's hospital for monitoring for this and vasospasm in patients suffering from subarachnoid haemorrhage.

In the 1984 CN curriculum (Appendix 9) TCD was referred to as echoencephalography, however this was not widely taught and to the author's knowledge the Wentworth Hospital neurophysiology unit in Durban was the only centre that incorporated the modality in practice and training. In fact, at that time TCD was a new modality internationally. According to Bathala, Mehndiratta and Sharma (2013), TCD for intracerebral blood flow detection was only introduced in 1982.

In the early 2000s the neurophysiology unit moved to the Inkosi Albert Luthuli Central Hospital (IALCH). This CN unit is currently, in 2023, still the only academic unit that offers training and assessment in performing and analysis of TCD investigations. However, certification in technical TCD expertise only became available in the United States of America in 2018 (Razumovsky *et al.* 2022). Within this context the fact that South Africa has had at least one training and assessment centre for nearly four decades shows the importance of this modality in neurocritical care.

All participants that selected TCD added relevant practical and theoretical skills. Given the sole training location, and therefore relatively low training exposure for this modality, it is perhaps unsurprising that TCD did not receive greater selection. It is however interesting that TCD is included in the clinical practice modules for all universities. The close to threshold selection frequency for a modality taught at only one training centre can be interpreted as indicative of the importance of this modality to industry. It may be beneficial for universities to further investigate incorporation of practical TCD training as an optional modality as it was in the 1984 document (Professional Board for Clinical Technology. 1984).

5.4.3 Modalities with no or minimal skills contributions during Q1

5.4.3.1 Maintenance of wakefulness testing

This is a sleep modality, and recording/reporting guidelines are shared with MSLT. The two are closely related and require the same recording environment and sleep stage recognition skills (Littner *et al.* 2005). According to Rosman (2006) there is consistent evidence that 15% to 20% of the South African population suffers from sleep disorders. The most common first patient complaint is excessive day time sleepiness (EDS). The MWT is the only objective measure to quantify this complaint in a regulated environment. The most common cause of EDS is obstructive sleep apnoea (OSA) which is evaluated by PSG, but once other causes of EDS are excluded the MWT can distinguish between subjective and objective EDS (Littner *et al.* 2005). Multiple sleep latency testing is primarily used to diagnose narcolepsy as a cause of EDS not attributed to OSA. However, when this test is negative objective EDS is important as untreated drowsiness during driving and operating heavy machinery can be fatal. It can also negatively affect memory and concentration (Maldonado *et al.* 2002; Littner *et al.* 2005; Waldman *et al.* 2020). The United Kingdom Driver and Vehicle Licencing Agency has instituted a fine of up to £1 000 for not disclosing diagnosed health causes of EDS (Sleep Apnoea Trust 2022) (United Kingdom Driver and Vehicle Licencing Agency. 2023).

Three Q1 participants selected MWT, and one contributed theoretical and practical skills required for this modality. However, these skills were inappropriate or non-related to the modality such as “You can perform flash and HV stimulation” and “Protocol takes shorter” (Littner *et al.* 2005).

Unfortunately, it appears that the importance of MWT is being overlooked, which, considering MSLT was selected as a core modality, was unexpected. Any facility offering MSLT can also offer MWT. The resource allocation and staff training for these procedures are also the same.

Maintenance of wakefulness can be taught without adding any practical training burden in any unit that offers training in MSLT. It is therefore recommended that the theoretical training should be combined with that of MSLT.

5.4.3.2 Memory testing and cortical brain mapping

From the historic documents it is not clear what was implied by “Memory testing”. Two types of MT are currently used in neurology and neurophysiology, both mostly performed by neurologists.

The first occurs during clinical neurologists’ cognitive patient examination (Tombaugh and McIntyre 1992), and the second is performed as part of intraoperative neuromonitoring during awake craniotomy for tumour resection (Ruis 2018). Intraoperative MT is conducted in conjunction with CBM where direct cortical electrical stimulation is performed, and the patient’s real-time functional and cognitive responses are monitored to ensure no eloquent brain tissue is removed (Bowman *et al*. 2016). This is done to limit clinical deficits post-surgery. Historical mention of MT more likely corresponds with clinical testing since IOM is a relatively new procedure in South African training centres. In 2018 Inkosi Albert Luthuli Hospital was heralded in international news for performing awake craniotomy surgery during which CBM and MT were performed (Jarvis 2018), and in 2023 Groote Schuur Hospital became the first academic training centre in South Africa to offer surgery for epilepsy treatment (Metelerkamp 2023).

Only two participants selected MT and three selected CBM. Of the participants that selected MT one commented that they had no knowledge of the modality and the other did not contribute any practical or theoretical skills during the skills section of the questionnaire. Only one participant contributed three practical and three theoretical skills required for CBM that showed overlapping themes relating to core modalities.

It is unclear why MT and CBM are included in two of the three UoT module descriptors as there is no core modality related to these modalities and the modalities themselves are unfamiliar to participants.

5.4.3.3 Deep brain stimulation

Deep brain stimulation is mainly used as treatment for movement disorders, in particular, Parkinson’s disease (Groiss *et al.* 2009). In 2013 five public sector hospitals had experience in performing DBS, however in 2023 this is still not a standard procedure in most training centres. This modality is highly invasive and only a few specialised centres in South Africa perform this service routinely, with South African procedure guidelines first defined as recently as 2017 (Anderson, Van Coller and Carr 2017). During DBS invasive "pacemaker" electrodes are implanted in the midbrain which is then connected to an implanted electrical stimulator placed under one of the clavicles on the upper chest of the patient (Medtronic 2020).

Of the three participants that selected DBS, one acknowledged that they had no knowledge of the modality. The second commented "Apply electrode prior to operation" as a theory skill. From this comment it is clear that this participant did not have relevant knowledge of this modality, as DBS electrodes are solely placed intracranially during surgery.

Only the third participant who selected DBS contributed relevant practical and theoretical skills.

5.4.3.4 Peripheral nerve ultrasound

This is a relatively new modality to CN internationally and is not formally taught at any academic centre in South Africa at present. Suk, Walker and Cartwright (2013) stated that this modality only emerged in the early 2000s, and the first international congress on PNUS was held in 2012. To the author's knowledge the Inkosi Albert Luthuli Hospital CN unit is the only training unit that routinely uses PNUS during neuromuscular injection procedures. The CNSSA hosted a PNUS workshop at the 2022 annual congress to introduce the modality to more CNPs. From feedback at the congress none of the attendees were at that time routinely using PNUS in private practice.

None of the three participants who selected PNUS were able to add any practical or theoretical skills.

5.4.4 Tone-burst and click brainstem auditory evoked potential

During Q1 qualitative skills statement submissions participants noted that BAEP testing should include tone-burst responses. Click responses target the whole auditory system and therefore are mainly a test of the central nervous system and not the hearing sense organ (organ of corti in the cochlea) (Husain 2018: 265-266). Tone-burst stimulation is considered an electrophysiological audiologic test rather than a neurologic test as the stimulus targets different areas of the cochlear sensory organ

(Verster 2022). The group consensus was that KT-Ss need to master both the response techniques.

Both techniques use the same patient connection methods and recording equipment only with different types of sound stimulus. Therefore, the technical and technological challenges related to recording small nerve action potentials are the same and within the scope of a CNP. It is important to note that audiological tone-burst threshold testing is not the same as clinical audiometric testing.

5.4.5 Long-term EEG video monitoring using surface and grid recordings subdural monitoring LTEM and intraoperative neuro-monitoring using multi-modality evoked potentials

Of the modalities included in the module descriptor documents IONM and SG LTEM are the most invasive. It is therefore not surprising that these two modalities showed the lowest selection frequency and importance rankings.

Although Q1 results indicate an industry need for these two modalities the complete dependence on prior mastering of all other modalities places these invasive modalities outside the scope of an undergraduate degree.

On 28 September 2019 an industry round-table discussion was held. It was unanimously decided that only theoretical understanding and possibly observational exposure should be included in the BHS undergraduate degree. Representation from all three UoTs were present, and the industry members asked for cooperation in developing a post-graduate qualification in IONM (personal attendance 28 September 2019, Johannesburg).

Although minimal introductory theory instruction may be considered it should be carefully considered against the workload related to core modalities. Theory introduction was considered only moderately important as a tertiary knowledge skill for mastering the fourth year by less than half of Q2 participants (Table 4.56). It would be more appropriate to ensure adequate theoretical and practical preparation by concentrating on the prerequisite modalities and related theory rather than adding additional material not related to graduate outcomes.

5.4.6 Non-invasive ventilation – positive airway pressure therapy

Professor Colin Sullivan patented nasal CPAP treatment after publishing his findings in 1981. Continuous positive airway pressure became commercially available internationally in 1988 (EdenSleep 2022; Barnes 2007). According to personal communication with Mr Peet Vermaak (private CNP and owner of Pretoria Sleep Lab, 23 July 2023) HFVAH obtained two Sullivan® ResMed® machines in 1993.

Historically NIV PAP skills training had been approached as part of PSG sleep apnoea studies. The object of PSG is to diagnose OSA and then monitor improvement during initiation and adjustment of NIV PAP treatment (Rosman 2006; American Association of Sleep Technologists 2012). This relationship was also reflected in practical and theoretical skills contributed by participants who selected PSG as an outcome modality. Questionnaire 2 tested this relationship and the results showed that NIV PAP should rather be classified as an essential PSG skill that needs to be mastered during PSG learning rather than an independent modality. However, mastering of this skill was found to be essential.

5.4.7 Pattern reversal evoked potential and flash visual evoked potentials inter-modality relationships

Both FVEP and PRVEP are used to evaluate the integrity of the visual sensory system. The PRVEP is of more clinical use due to higher specificity, but also much more challenging than FVEP (Robson *et al.* 2018).

During Q1 FVEP scored very low on the inclusion importance rank multi-voting question. This may be due to the more limited clinical application of FVEP which is limited to the very young or uncooperative (Husain 2018: 59-60), or those patients with such advanced optic disease that higher sensitivity and specificity tests are not feasible. FVEP is therefore a very valuable skill for occasional use with lower specificity and sensitivity than more preferred modalities such as PRVEP (Robson *et al*. 2018).

Inclusion was retested during Q2 where more than three-quarters of panellists included FVEP as essential when presented with evaluating FVEP on its own and not in comparative importance to other modalities.

The PRVEP inter-modality relationship with FVEP was strong and indicated PRVEP is dependent on prior knowledge of FVEP. This was supported by the high average learning importance rank which was the strongest prerequisite learning rank for PRVEP.

When investigating FVEP inter-modality relationships a similar finding was made of high overall modality relationship. There was a secondary agreement power on PRVEP dependence on FVEP with the same average importance rank as was found during PRVEP investigation.

5.4.8 Electromyography and nerve conduction studies

Clinically, NCS and EMG can be seen as two testing modalities used to answer one clinical question. This can be seen where EMG and NCS modality textbooks are combined such as Preston and Shapiro (2021) and the 1998 Neurological Association of South Africa congress booklet “Principles in the Practice of Nerve Conduction Studies and EMG” (Baker and Lotz 1998).

At the onset of CN WIL training and early NCS/EMG modality development in South Africa EMG was included in CNT training (pers. comm. Mr P Vermaak 10 October 2019 and Professor P Bill 08 February 2020). However, with the gradually decreasing WIL period in academic units in combination with increasing modalities CNPs needing to be trained in academic units were neglected in favour of neurology registrars who were prioritised by those units for EMG training. This resulted in CNPs receiving little or no practical experience in performance of EMG. Additionally, with the advent of the B Tech degrees not requiring training in an accredited training unit the training opportunities were not available to B Tech students outside of academic units.

This failure in training is problematic as a critical procedure in the CN scope of practice is excluded from training in neurology-controlled units.

The higher number of questionnaire participants reporting private practice rather than independent practice registration is likely responsible for the high importance of EMG training. Independent practice category CNPs are more likely to be older and training in EMG would more likely have been an expected part of their WIL (Figure 4.3, Figure 4.29 and Table 4.57).

This division between training experience of pre-B Tech practitioners that spent their complete WIL period in a combined CN and neurology WIL unit, in comparison with graduates who spent the majority of their training time outside of such a unit, is seen as the likely reason for the dissensus on inclusion of EMG in undergraduate WIL training.

In clinical practice it is impossible to do a complete neuromuscular electrophysiological examination without both EMG and NCS (Gutmann 2003; Chichkova and Katzin 2010). Therefore, it becomes impossible for a CNP to practice independently from a neurologist if minimum WIL training does not require EMG proficiency for graduation.

The alternative is that CN graduates gain post-graduate experience in EMG and this is reflected in the number of post-B Tech graduates that seek international EMG training. Electromyography was the only modality that at the end of Q1 showed a COV of > 0.5 reflecting the selection frequency finding of grouped selection on either the highest or lowest skills ability.

5.4.9 Modality selection conclusion

Of the eight modalities that did not meet core outcome modality criteria, three stood out.

Drug administration and management of adverse effects were found to be embedded knowledge and skills rather than an independent modality. Therefore, this modality was not truly eliminated, but rather reclassified as critically important for the mastering of core modalities.

The less than 75% agreement on the exclusion of SG LTEM and IONM leaves room for limited foundational theoretical instruction. Complete mastering of performance, analysis, and reporting of the prerequisite modalities would prepare graduates for further post-graduate training in these two modalities.

The occurrences of modality selections with skills comments regarding lack of training exposure with multiple incidences of a participant stating, “I have no knowledge of it”, and another participant listing inappropriate skills, are unsettling.

Private practitioners selecting modalities and listing unrelated skills causes concern regarding patient care and whether appropriate procedures are performed. The comments regarding having no knowledge of a selected procedure raises the same concern and additionally questions why the participant would consider these as core outcome modalities. These only occurred in non-core modalities and therefore did not have any effect on aggregate modality selection outcomes and did not affect the validity of the data.

Participants' acknowledgement of the lack of training in core modalities reiterates the problem of non-standardisation of training and the need for aligning training with industry needs. This also speaks to honesty in answers and justifies the strict blinding of the identities of these participants.

It is worrying that, upon review of Q1 responses, some CNPs were not familiar with all modalities and even confused two or more for the same or clearly did not know what the modality was. For example, PNUS and NCS, MWT and wake EEG, overlapping comments under cICU EEG with bedside short recording cICU EEG.

Participants who only contributed skills outcome levels without contributing skills also raised a question of whether skills outcome level selections would have matched the listed skills. This is however not considered detrimental to the results as round two consensus showed group agreement on the aggregate outcome skills level responses.

What is more troublesome is the participants who indicated a modality as essential and then in the skills contribution section indicated no knowledge regarding the modality. This raises questions regarding the training and practice of the participant. Unfortunately, some participants stated that they did not receive any training in a chosen modality. This is an indictment of our current training and, if true, the structures they trained in have failed our patients.

5.5 Modality affinity diagram

Four TLA levels were identified flowing from initial learning of routine EEG (Figure 5.1).

The second most important modality was found to be bedside EEG (second level TLA importance) with the most dependant modalities. Nerve conduction studies, BAEP, and FVEP formed the rest of the second level TLA modalities, with EMG, SSEP, and PRVEP as third level dependents. Electromyography was the lowest priority outcome modality during weighted average importance rating in Q2 results (Table 4.9). This was despite a relatively high participant selection frequency of 76% in the n = 50 participant group during Q1 essential modality selection (Table 4.1).

The third level of dependency of the EEG modality group splits the sleep modalities from the more dependent EEG modalities and include neonatal EEG and PSG (Table 4.34, Table 4.13, and Figure 5.1).

The fourth level of TLA modalities below neonatal EEG are cICU EEG and SE LTEM and below PSG is MSLT (Table 4.39, Table 4.41, and Figure 5.1).

The deepest level of learning dependency is occupied only by IONM and SG LTEM – the two modalities that did not meet inclusion criteria as core modalities. Additionally, these two modalities are also the only fully invasive modalities.

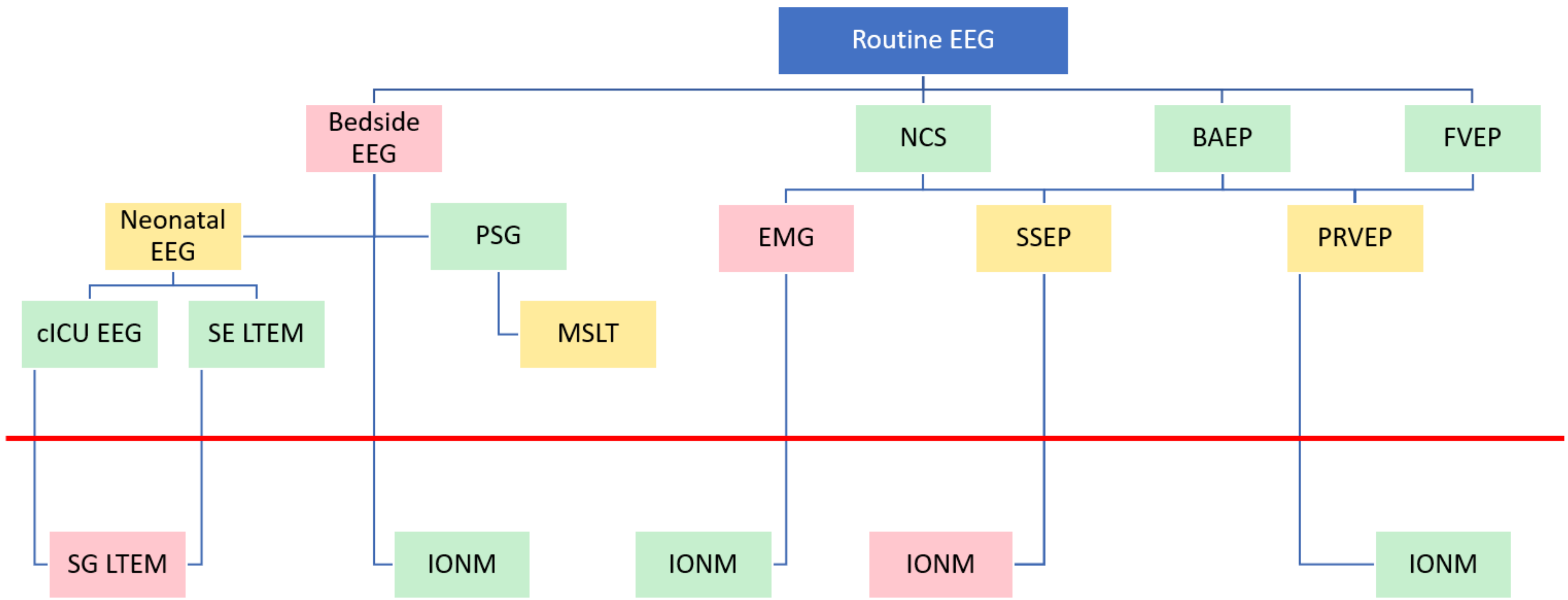

Figure 5.1: Modality learning dependency affinity diagram

Core modalities are represented above the line. Modalities under the line were not considered appropriate for mastering during undergraduate study.
Colour coding indicates primary (light red), secondary (light green), or tertiary (light yellow) dependence on the preceding modality level (see Section 4.11.)
Abbreviations: BAEP – brainstem auditory evoked potential; EEG – electroencephalogram; FVEP – flash visual evoked potential; IONM – intraoperative neuromonitoring; SG LTEM long-term EEG monitoring with subdural grid electrodes; SE LTEM – LTEM using surface electrodes only; MSLT – multiple sleep latency test (); EMG – electromyography; NCS – nerve conduction studies; SSEP – somatosensory evoked potential.

5.6 Thematic analysis categories

It was interesting that the skills and knowledge thematic analysis did not cover all CT functions, duties and task activity categories as set out by the 1994 task team (Human 1996). The majority of participants (according to mean practice period and the majority of private practice registrations) were trained in the period after B Tech inception and decrease in academic unit clinical training time. There seems to be a correlation between a decrease in clinical training time and recognition of functions, duties, and tasks. This is of concern as our CT and CN scope of practice is continually expanding.

The absence of training and research as definitive and concrete functions or duties of a KT or KTG is unsettling as the future of our profession is dependent on continued training and research. The lack of importance of training would be consistent with the low number of accredited training units for CN. The absence of research is problematic as this indicates a shift away from growth in knowledge and stagnation in practice standards.

5.6.1 Skills discussion

5.6.1.1 Quality control

Nineteen quality control skills were identified during thematic analysis (Table 4.47). Accurate measurement according to the international 10-20 system showed the highest TLA relationship to SE LTEM, the lowest priority modality on the training affinity diagram. This finding is difficult to accept as all international guidelines for procedures including placement of cephalic electrodes stress the importance of accurate electrode placement according to the 10-20 system nomenclature (American Clinical Neurophysiology Society 2006a, 2006b, 2006c; Cruccu *et al.* 2008). The exception is VEP where a second international measurement system, the queen square placement system, is indicated for electroneurophysiological investigation of the post-ocular nerve visual pathway pathology (Holder *et al.* 2010; Robson *et al*. 2018).

This finding is in contrast with the primary importance power of “Apply protocol/minimum standards in all environments and all patients” and “Repeatability/reproducibility of serial tests”. The concern is that measuring is not taught as a principal part of minimum standards. Once again, this raises concerns regarding qualified CNPs knowledge of international minimum standards.

Intensive care unit artefact recognition did not show essential affinity to those modalities not typically or ever performed in ICU. This was an expected outcome. Replication was isolated to only EP modalities which is appropriate.

The only modalities with a primary importance selection frequency for management of sleep were the sleep modality group, namely, bedside EEG and routine EEG. The highest TLA relationship was with MSLT – a fourth level modality.

The low importance rating for sleep management scored under the quality control skills selections for EP and neonatal EEG modalities display a lack of understanding or knowledge gaps in relation to accurate interpretation of results. Fluctuation in level of sleep and wakefulness is undesirable for recording of cortical EPs (Husain 2017: 13) and neonatal EEG guidelines include specific recommendations regarding importance of recording sleep in this population (Sinha *et al*. 2016; Tsuchida 2016)

The impact of this scoring shows a lack of knowledge or understanding of the effect of sleep on these modalities.

EMG most likely received the least primary quality control embedded skills as a reflection of the recording differences between EMG and all other modalities and the lower level of consensus on inclusion and learning order of EMG in comparison to other core modalities.

5.6.1.2 Analysis skills

Correlation of video recording and identifying of sleep features showed the highest number of non-related modalities. Modalities that showed a secondary or tertiary relationship with the correlation of recording to simultaneous video recording included the EEG and sleep modalities. These are the modalities where technical recording standards include recommendations on simultaneous video recording and a higher level of importance was expected, particularly since most sleep investigations are not directly observed and video recording is required for clinical event correlation with recorded data for both sleep and EEG modalities (Nuwer *et al.* 1998; Berry *et al.* 2012; Sinha *et al.* 2016; Tsuchida 2016; Peltola *et al.* 2023).

The high number of modalities selected as having no TLA dependence on identifying of sleep features are expected. These include modalities where scalp recording is not performed (NCS, EMG) or where recording density is insufficient to resolve sleep features (EPs).

5.6.1.3 Performance skills

The low level of importance of needle electrode placement and techniques for recording and stimulation with EMG was unexpected. EMG is primarily a needle electrode examination and is performed by placing a concentric needle electrode in selected muscles for recording electrical potentials. Near-near NCS are also performed using needle electrodes at both recording and stimulating sites. This ambiguity may be due to the dissensus regarding training inclusion of EMG and possibly indicates a lack of knowledge of performing this modality and the infrequent use of needle methods in routine NCS. Both these methods, EMG and NCS using needle electrodes, are contained in the scope of practice of CN, and knowledge of the methods should bear higher priority.

Unfortunately, few training units still include training in these methods, partially due to the greater incidence of neurologists conducting EMG investigations in academic units and KTs and KT-S, therefore, being excluded from learning.

Surface electrode stimulation techniques showed a primary importance power with NCS and SSEP, as expected. What was however not expected was the tertiary and secondary relationship to all other modalities, including long-term, EEG, and sleep modalities that make no use of stimulation techniques.

Intubated patients are frequently encountered during bedside EEG recording in high-care nursing wards, ICU and neonatal ICU (NICU). The low TLA priority, or power of relationship, of management of intubation and SpO_2 is interesting as these are required for maintaining patient safety during patient manipulation and positioning – a skill that did receive primary importance for TLA of all modalities. SpO_2 and other vital signs are also of importance with sleep modalities (American Association of Sleep Technologists 2015).

The low importance selection power of “Manage patient events/emergencies” and “Manage side effects to testing or treatment” as primary TLA skills contrasted with “Maintaining of patient safety” but correlated with the low importance of the BLS/CPR skill.

Setting up of video recording forms part of the recommendations for recording all EEG and sleep modalities (Berry *et al.* 2012; Peltola *et al.* 2023). Only cICU and SE EEG received a primary importance rating with bedside EEG being scored as a secondary importance skill. Both the sleep modalities as well as neonatal and routine EEG scored only a tertiary importance rating for this performance skill.

This is in contrast with the importance ratings of the knowledge skills "Importance of technical sufficient recording" and "ACNS/IFCN protocols (minimum technical requirements) that showed a high level of consensus as essential third-year outcome skills.

This contrast in importance ratings between essential performance skills and embedded knowledge skills seems to indicate lack of knowledge of the minimum performance guidelines for these procedures, or understanding the implementation of these guidelines.

Flash VEP and EMG scored the lowest relationship with the performance skill "Adjust protocol to obtain relevant information". In the case of FVEP this is not surprising as this modality does not lend itself to much modification. However, the EMG test modality protocol is patient and question specific and must be modified for each patient and even during the examination. The low importance of modification is attributed to both the minimal training in EMG and the communication skill relationships with EMG that will be discussed in the following section.

5.6.1.4 Communication

According to a study conducted by Joubert and Botha (2019), the prevalence of disabling hearing impairment in the Elias Motsoaledi Local Municipal area in Limpopo was 8.9%. A 2016 study by Ramma and Sebothoma (2016) showed the prevalence of disabling hearing impairment in the Cape Town area to be 4.6%. London, Zweigenthal and Heap (2020) investigated access to healthcare for the deaf in South Africa and found that these figures reflect global numbers. Penn (2007) found that 80% of healthcare encounters are limited by language barriers. The review conducted by London, Zweigenthal and Heap (2020) found that this language barrier is further confounded in patients with hearing disabilities. These persons can be part of any of our patient populations. Haricharan *et al.* (2013) investigated hearing disability in health care from the patient perspective and quoted a participant as saying: "I try to ask a question again if I don't understand, … they just write something down. They don't have patience. They are too busy to write everything … I can't understand them". However, the only modalities where communication with the hearing disabled were selected as of primary importance were routine EEG, BAEP, PRVEP, and bedside EEG, all of which are harmless and unlikely to cause injury. It is notable that in the modalities where electrical stimulus (NCS, SSEP) and needles (EMG, NCS, and SSEP) are integral to performance of the tests communication with the hearing impaired was not scored as of higher importance. This is contradictory to the skills of "Bedside manner: patient interaction/communication" and "Obtain cooperation / all ages / explain procedure" which both were indicated as primary importance for all modalities. In May 2023 the South African National Assembly approved the Constitution Eighteenth Amendment Bill [B1 – 2023] which recognised South African Sign Language as an official language in South Africa (National Assembly 2023). On 19 July 2023 the President signed this amendment into law and South African Sign Language become the country's 12^{th} official language. f

It was expected that "Working with theatre staff" showed the least number of related modalities (routine EEG, SSEP, and SE LTEM) with a relatively low relationship power. This is expected as none of the essential outcome modalities are theatre specific.

The finding of "Communication with ICU staff" as the second least important communication skill was surprising. Except for PRVEP and MSLT all other core modalities can and do occur in the ICU setting. The modality that stands out is neonatal EEG which is most often performed in an ICU setting due to the vulnerable nature of this population.

The ability to "Communicate staff Drs, nurses, and colleagues" had a primary importance power relationship with all modalities except EMG. This may be related to the low consensus regarding EMG as a core modality and the dissensus regarding TLA skills outcomes and high frequency of N/A selections during the outcome skills level selection. However, this is the one modality that in practice is most often performed in collaboration with a neurologist. Referring to Q1 results where "Assist with EMG" received a 41% selection rate (Figure 4.19), a higher relationship power would have been expected. This may reflect the current situation where EMG may not be being taught in some units, especially private practice units.

The skill for “Protocol and procedure development” and “Communicate with staff Drs, nurses, and colleagues” goes hand in hand and is required for the performance skill of “Adjust protocol to obtain relevant information to question”.
As mentioned in Section 5.6.1.3, FVEP and EMG scored the lowest on adjusting protocols to obtain relevant information. The EMG examination is led by firstly the clinical presentation of the patient and relates to the skill “History/pre-test evaluation” where EMG scored a moderate power, and secondly by the outcome of the NCS test which relates to the performance skill of “Integrate results from multiple tests”. EMG scored a low relationship power and NCS only a moderate relationship power to this skill. Communication with the referring doctor, and in many instances, the neurologist involved in the EMG, is essential in this examination where a CNP is collaborating in a patient encounter which cannot successfully be completed without applying all these skills in unison.

5.6.1.5 Personal attributes

Dexterity or fine motor control is more a physical ability than a personal attribute (Makofske 2011), yet it was selected as of primary importance for all modalities except PRVEP where it scored one point under primary importance. This finding then points to identifying this innate personal attribute in candidates prior to starting specialisation, or at least clearly communicating the requirement to students prior to specialist category selection.

The low number of personal attributes that showed a primary learning importance relationship to EMG is possibly a reflection of the ambiguity that exists regarding the inclusion and skills level outcome of EMG as part of the undergraduate qualification. Understanding the patient experience by undergoing the procedure was selected as being of primary importance for the majority of core modalities and of secondary importance to the rest. Surface electrode LTEM, neonatal EEG, and cICU EEG are arguably not feasible to undergo outside of being a patient and showed the lowest importance selection frequencies. Electromyography is the most invasive modality which may account for the secondary importance selection. The highest relationship was with NCS. This modality is commonly practiced by students on each other and mentors during training. Patient preparation and practice of the pre-test procedures MSLT and PSG are also often practiced on fellow students which makes the lower importance of this personal experience an unexpected finding. This may be because it does not require undergoing the full procedure, but only part of it.

5.6.2 Knowledge skills discussion

5.6.2.1 Third year knowledge skills

During third year knowledge analysis “Indication of testing / clinical application” had a score of one point less than primary importance. It was therefore classified as a secondary third-year outcome. However, it had an overall 90% selection power and 90% agreement as an essential course outcome (Table 4.53). Unlike the other secondary essential outcomes this skill did not have significant power selection as a tertiary outcome for fourth year study. In most instances secondary importance skills during third year show lower secondary or tertiary importance during fourth year. This analysis would mean skills that have lower learning importance during fourth year may be primarily taught during third year and refined during fourth year. However, “Indication of testing / clinical application” does not have fourth year TLA representation and as such learning must be completed during third year to achieve the desired outcome upon graduation.

“Digitisation of recordings (example: analog to digital conversion)” was selected as a primary knowledge skill for third year students to master. In contrast it also received the highest N/A power of the primary third year outcome knowledge skills. Likewise, the related secondary knowledge skill of “Equipment hardware and software options” received the same N/A power rating. This contrasted with the very high agreement that both the knowledge skills of “Digitisation of recordings” and “Equipment hardware and software options” are essential graduate course outcome knowledge skills.

Further, four embedded practical skills that depend on these two knowledge skills were selected as of primary importance to all core modalities (Table 4.47, Table 4.49, and Table 4.50).

These were:

- Troubleshooting and correction: technical problems (example: equipment position, hardware, and software)
- Artefact recognition/differentiation from activity of interest: correction; non-physiologic

- Equipment machine knowledge / setting manipulation (example: changing filters, programming amplifiers)
- Calibration and maintenance and testing of equipment.

This dichotomy in importance possibly reflects practical TLA nearly exclusively performed using digital equipment and the ease of use of pre-setup equipment. The importance of foundational knowledge in working principles of equipment therefore needs to be better conveyed to KTs involved in training, and KT-S in current training. It is imperative to ensure that future graduates know the primary operation functions of the equipment used because not recognising or delaying the correction of equipment errors can lead to serious patient complications and injury.

Basic life support/ Cardiopulmonary resuscitation had a 4% N/A selection power, however any person practicing a healthcare profession should ideally be able to supply this lifesaving skill. Basic life support certification is required for initial registration as a healthcare practitioner with the HPCSA RCT, however current registration is not part of the continuing professional development requirements for maintaining active registration status and is therefore not seen as a priority. This contrasts with international qualifications that require initial and continuous active basic life support certification for periodic reregistration. One would have hoped that individual practitioners would see the importance on a personal level, however results show voluntary continuous certification is not highly regarded, so regulation is required in line with international standards for similar professions (ABRET 2022a, 2022b, 2022c, 2022d, 2022e, 2022f; Lopez *et al.* 2023).

Likewise, “Contra-indication and side-effects of testing” also showed a 4% selection power of N/A. This can lead to life-threatening events, most notably in cardio-vascular patients and routine hyperventilation during EEG and use of needle electrodes in patients with bleeding risk.

Knowledge of differences in related modalities was also indicated as N/A by 4% of Q2 participants. Lacking this knowledge could lead to incorrect procedures being performed.

Due to the primarily non-invasive nature of CN testing this would not likely lead to primary patient harm, but the effects of incorrect diagnostic data would cause secondary patient harm through incorrect diagnosis and delay in time to treatment.

5.6.2.2 Fourth year knowledge skills

The majority of fourth year knowledge skills have a secondary or tertiary TLA importance during third year (Table 4.55 and Table 4.56). Therefore, fourth year TLA of these skills will necessarily be an advancement of existing knowledge and refinement of skills, rather than primary new learning.

This is reflected in the singular primary TLA skill for fourth year "Give diagnosis and suggest additional investigations". This skill would be dependent on several primary and secondary third year TLA skills (Table 4.52 and Table 4.53).

Such as:

- Electrophysiological presentation of normal physiology (normal results – patterns)
- Anatomy pertaining to modality (physical location and connection / relation of structures)
- Physiology pertaining to modality (generation of activity – function of the anatomy)
- Identify critical abnormalities requiring immediate medical intervention (status epilepticus)
- Age related abnormalities
- Age related maturation of electrophysiology results
- Pathophysiology and diseases/diagnosis pertaining to modality (dysfunction of anatomy being tested, including interrelated organ systems affecting anatomy under investigation)
- Importance of GA and CA (know how to calculate)
- Clinical utility of different recording parameters – what physiology is assessed through each parameter or sensor
- Patient variables effect on results (technical and physiological)
- Expected clinical presentation of known pathology
- Localisation of lesions (identify anatomical location)

Although TLA of the skill "Give diagnosis and suggest additional investigations" was clearly indicated as suitable for fourth year study, it was not essential for graduation and only a tertiary agreement on suitability of the outcome level was found.

A high level of agreement was found that TLA is limited to fourth year of study with a low agreement that this skill should be included as a low priority skill. It is therefore essential for learning to occur during fourth year, rather than being an essential outcome for passing fourth year of study. This is then an advanced skill and desired but not required of our graduates.

"Disease specific testing protocols (examples: CIDP; optic neuritis; BRECTS)" was found to be essential for graduation with a high level of consensus. However, the group consensus on outcome year was tenuous with only a small majority selection power for secondary learning importance for fourth year rather than primary importance for third year.

The only primary graduate knowledge skills (Likert rating as essential) that were selected as secondary fourth year outcome skills with a low level of agreement for course inclusion were neuropharmacology and "Effect of UNRELATED pathology on test results". This difference between graduate importance vs. agreement on inclusion illustrates the advanced nature of these skills.

Knowledge relating to "Ethical billing" scored only a moderately important rating by only two-thirds of participants and the inter-rater agreement was only 74%.

5.6.3 Conclusion

As primary independent diagnostic healthcare professionals it is concerning that greater importance is not placed on TLA of skills that can negatively impact patient care and ethical practice. It may be necessary to do continuing professional development education regarding the importance of these principles.

5.7 Post qualification experience and training involvement of participants

The high number of participants with past or current training experience (Figure 4.2 and Figure 4.30) that contributed to the modality learning dependency questions supports the validity of the data regarding embedded knowledge and skills linked to teaching learning and assessment per modality. Likewise, the vast distribution of post qualification experience (2 to 33 years) indicates respondents with both extensive experience in CN requirements and recent graduates with a more immediate understanding of the learning process. This would then support the validity of the findings of both industry outcome needs and training relationships between modalities and the required embedded skills.

5.8 Practical experience and training time

Section 4.15 reported the proposed minimum numbers of unassisted logbook procedures in each core modality to achieve full proficiency. In 2017 the author compiled a procedure time summary as part of her management duties at an accredited Department of Health training facility. This looked at the time burden per procedure for qualified staff. This summary was used to estimate the required time necessary to complete the proposed number of logbook procedures.

The total number of required clinical hours to achieve the proposed logbook numbers of unassisted experience per modality was calculated as equal to approximately 2 400 hours of uninterrupted proficient work.

It must be taken into consideration that this excludes the time taken for instruction, practice, and learning performance of these procedures and does not include interpretation and reporting. Learning per procedure often takes longer than eventual experiential patient procedures.

To complete the industry requirements for individual patient encounters the full 3 840 clinical hours must be solely dedicated to CN training rather than being offset towards first- and second-year activities or non-category-specific lectures during designated clinical hours.

5.9 Reflection on pre- Bachelor of Technology training

The final core modalities and outcome skill levels from this study were similar to the outcome standards of Subject 11 (Biomedical Apparatus and Methodology) and 12 (Clinical Practice) of the 1984 National Diploma (N Dip) qualification (Appendix 9) (Professional Board for Clinical Technology 1984), namely:

- Routine EEG
- Mobile EEG (bedside)

- Overnight and short sleep recordings including heart rate and respiration recordings (polysomnography).
- Mobile recordings in critical care setting
- Electromyography
- Electroneurography
- Visual evoked potentials
- Somatosensory evoked potentials
- Auditory evoked potentials

Upon completion of the 24-month WIL period, interpretation of results was expected for all modalities and this requirement is reflected in the results of this research.

The noticeable differences between the 1984 documents and the current courses in training and this research are the absence of neonatal EEG as a separate modality in the 1984 outcomes and the nonexistence of long-term EEG and NIVPAP therapy. These can be considered representative of the technological progress made since the analog to digital transformation. Until the late 1990s the majority of EEG recordings were still performed using pen and paper systems (personal experience of the author) making long-term EEG recordings impractical.

5.10 Reflection on the National Diploma and Bachelor of Technology combinational offering

In the first nearly four decades of the CT educational journey, the cornerstone of category specialisation was achieved through National Diploma (N Dip) work integrated learning (WIL) in conjunction with completion of four category-specific subjects during initially the second and third years, and later only the third year of enrolment. All universities shared a content syllabus with detailed anatomy, physiology and pathophysiology content for the CNT specialist subjects (Professional Board for Clinical Technology 1984). The clinical practice subject required mastering routine and mobile EEG modalities, short and long PSG and sleep modalities, EMG, NCS, and the EP modalities BAEP, VEP, and SSEP. Transcranial Doppler, known as Echoencephalography at the time, was listed as an optional modality and not required for examination. The subject description also included sections on patient safety and administrative skills.

In the 1991 TOFS B Tech curriculum, the fourth year included an additional year of specialised clinical practice, pathophysiology, and biomedical apparatus and methodology study. However, in 1997 the B Tech subject enrolment at CUT was limited to Principles of Management, Research Methodology, and an advanced category-specific specialist subject without a minimum experiential period (Technikon Free State / Central University of Technology 1997). Students were also required to complete a personal research project and thesis as an outcome. A TUT prospectus document listed the modalities of EEG, PSG, EP recordings, EMG and neurography (NCS), however, the subject assessment was noted as an evaluation of the research project. A TOFS syllabus document consisted of a single page listing electroencephalography, polysomnography, evoked potentials, and electromyography/neurography. No further information was supplied.

In 2002 the HPCSA RCT developed guidelines for minimum standards in outcomes-based training in CT (Board for Radiography and Clinical Technology 2002). One of the aims was to give modality competency and proficiency content guidelines for N Dip and B Tech.

These problematic guidelines for CN as shown in Figure 5.2 were still in use in 2013 (pers. comm Dr E Vermaak 20 Aug 2013). The list of training requirements for both N Dip and B Tech did not include nerve conduction study competency or proficiency which this study showed falls on the second level of the modality learning dependency affinity diagram (Figure 5.1). As iterated earlier, students were not required to complete their B Tech studies in an academic or accredited training unit to obtain the advanced reporting skills.

In 2005 DUT's document for CN N Dip had been amended and added "Perform and report transcranial Doppler studies; Perform and report nerve conduction studies; Perform and report long-term monitoring studies". Between 2017 and 2019 DUT's Advanced Neurophysiology B Tech subject included a practical proficiency assessment for multiple modalities including routine EEG, nerve conduction studies, multiple evoked potentials, and TCD.

NEUROPHYSIOLOGY
Diploma
Under supervision:
perform electroencephalography
analyse EEG result and generate report for verification
perform evoked potentials (visual, auditor and somatosensory / brain auditory)
assist with electromyography

B Tech
Independently:
perform and report on polysomnography (neurological and respiratory).
report on electroencephalography
report on evoked potentials
perform and report on narcolepsy studies
perform and report transcranial doppler studies

Figure 5.2: 2002 RCT Neurophysiology clinical outcomes for N Dip and B Tech
Source: (Board for Radiography and Clinical Technology 2002)

By 2013 the CUT internal document had been further revised to include "Electroencephalography (EEG), Multiple sleep latency test (MSLT), Polysomnography (PSG), Nerve conduction studies (NCS), Electromyography (EMG), Transcranial Dopplers (TCD), Evoked potentials (EP), Long term epilepsy monitoring video studies (LTEM), Brain mapping, Memory testing and WADA testing, Drug administration and management of side effects."

Although there was very little inter-university overlap with the content and assessment of the B Tech year, the N Dip third year universally included the four foundational subjects. Training units therefore had a historical roadmap and the four core subjects' content remained unchanged. Even though all units did not train the same modalities, all N Dip graduates were required to pass category-specific anatomy and physiology and the core modalities were still mostly assessed according to the 1984 document. Thus, a universal national expectation of competency of N Dip graduates was mostly maintained until the 2002 HPCSA guideline that delineated modalities between N Dip and B Tech.

5.11 Reflection on the Bachelor of Health Science

While studying the third- and fourth-year neurophysiology module descriptor documentation of the three universities it became apparent that two (DUT and CUT) are very similar regarding subject offerings, while the other (TUT) deviated towards maintaining the N Dip/ B Tech structure with standardised third- and fourth-year practical assessments and category specific anatomy and physiology subjects during the third year (Figure 2.5, Figure 2.6, and Figure 2.7).

The most startling change was the elimination of third-year specialist category anatomy and physiology subjects at CUT and DUT and the move toward group research projects at DUT and TUT.

All the specialist anatomy and physiology-related knowledge and practical skills were considered essential for achievement of graduate outcomes during this research.

It is the international standard for training accreditation to include detailed standards and guidelines not only in which modalities should be taught, but also the methods and graduate competency expectations (Board for Radiography and Clinical Technology 2009; American Academy of Neurology *et al.* 2011; Kekana 2011; American Academy of Neurology *et al.* 2017a, 2017b, 2020a, 2020b, 2020c, 2020d, 2020e, 2022a, 2022b, 2022c, 2022d).

The loss of research as a CT duty category in the results of the skills analysis indicates that greater importance on individual participation in research needs to be promoted. Graduates need to realise the impact that continued international research has on our profession and it is our duty as CNPs to represent the interests of our patients by contributing equally.

Supplying training units with prescribed modality-specific training content guidelines and minimum outcome skills for training can address the findings of practitioners either not having been trained in certain procedures or being unaware of the importance of embedded skills. Standardisation between units within a university would be a first step towards national standardisation in training. This would also be in line with the United States where per-modality outcome guidelines are provided as part of training unit accreditation (American Academy of Neurology *et al.* 2020c, 2020d, 2020e, 2022a, 2022b, 2022c, 2022d).

The high level of industry engagement with this research implies industry investment in training. Furthermore, full collaboration on final examinations between universities and industry representatives can be undertaken for national standardisation of graduate skills and abilities. Inviting industry representatives to witness standardisation in examinations will help to rebuild trust in the level of our training outcomes.

A national examination per category involving all three universities would be ideal. Although this may be impractical in larger categories with a greater number of students, it should nevertheless be possible given the small number of CN graduates per year.

5.12 Reflection on implications for professional registration

There is great variation in outcome assessment measures between the universities and no standardisation of modalities included in training. This contrasts with the pre-B Tech period where combined national examinations were conducted. It is also in contrast to current medical specialist examinations in South Africa which are standardised and independent from university assessments (The Colleges of Medicine of South Africa 2023).

In CN internationally there is a tendency toward national board examinations. Not all countries require registration for professional practice as CN professions may not fall under a regulatory body such as the HPCSA.

In South Africa our profession is governed by the HPCSA and one of the key mandates of the council is maintaining patient safety (South Africa 1975: 8-10). This places our country in a better position to ensure that all patients receive care by equally proficient CNPs.

The HPCSA needs to ensure that all graduates who are added to the roll for independent practice registration are equally qualified. One of the measures that the council can take independently is stricter training unit accreditation standards with greater emphasis on graduate outcomes rather than exposure opportunities.

5.13 Challenges

5.13.1 The impact of the COVID-19 pandemic

The COVID-19 pandemic lockdowns and strain on the medical field interrupted initial background interviews. It placed huge time constraints on both the researcher and potential participants. Between March 2020 and December 2020, the researcher had little time to spend on research and final ethics submissions and permissions were also delayed due to university closures and backlogs.

As a public service hospital and an academic training centre IALCH was hard hit by the health service impact the revoking of WIL KT-S and B Tech KT interns and the temporary moratorium on volunteer workers. This impacted both the BHS KT-S and B Tech KTs volunteer interns' presence and left IALCH with only the author and one production CNP for nearly 6 months. This shifting of workload resulted in little time to pursue personal research. Upon lifting of the placement moratoriums, the author was inundated with BHS lecturing, B Tech tutoring and project supervisor responsibilities. This time-overwhelming workload eventually led to the author's resignation as a third-year BHS part-time lecturer and tutor.

5.13.2 Delays in creating and launching questionnaires

5.13.2.1 Training and direct assistance in programming of questionnaires

Mastering of the QP survey system presented a time-consuming challenge. There was no local support or university training available. Communicating with the international helpdesk required navigating time zone differences and 24-hour delays with answers from multiple persons with different levels of understanding.

The process of setting and testing Q1 lasted months instead of weeks, leading to Q1 launching prior to the final workflow/logic settings test by the QP helpdesk. This unexpected last-minute helpdesk validation test resulted in nine Q1 participants multi-voting question validation settings being set to "at least 10" instead of "at most 10". The effects are discussed in Chapter 4 Results, Section 4.2 and 4.3.

Online participation rates were slower than expected due to the launch over year end and private medical practitioners still getting back on their feet after the lifting of the hard, COVID-19, lock downs. The participation window for Q1 was therefore extended.

QuestionPro® licencing required all qualitative theme analysis to be handled manually offline and other statistical challenges delayed the setting of Q2.

5.13.2.2 Survey distribution

The QP survey distribution desktop uses an email proxy to send and track invitations. This requires the university's internet security protocols to allow QP servers access to send and track emails on behalf of the investigator.

Between launch and Q1 and Q2 the DUT information technology security settings were changed to prevent this required access. The first few launces of Q2 failed and no invitations were made as licencing and information technology security settings prevented distribution of Q2 through secure servers.

The QP helpdesk assisted in finding a work around using free email addresses. Sending invitations this way requires simple mail transfer protocol (SMTP) access permissions. This required three-way passing of directions between the QP helpdesk and the researcher to the DUT administrator.

Each email service provider has individual limits on the number of proxy emails that can be routed before a spam warning is issued and the address is frozen. Two of the first proxy email addresses were frozen and only one could be recovered.

Replies started coming in after the researcher obtained permission from CNSSA to post reminders and requests to check spam folders for participation links on the CNSSA bulletin groups.

Questionnaire 2 was open for four months to allow for repeated launching and individual link creation. It was impossible to gauge the effectiveness of distribution and the researcher received requests for participation post-closure and reports from CNPs that they never received follow-up invitations.

5.13.2.3 Participation per question tracking

The QP survey platform offers no way of tracking how many participants answer each individual question. The drop-out analysis only indicates the last question answered by participants but does not include individually skipped questions.

When analysing the prerequisite vs dependency framework questions, it was important to calculate the percentage of selection frequency according to the actively contributing number of participants. This was important as selection ratios between dependent and prerequisite values for learning formed the foundation of determining interdependent relationships for TLA on which the affinity diagram was built and formed the foundation of the WIL content framework. This required a time-consuming manual audit of the relevant questions to determine how many participants were actively making selection choices.

5.14 Strengths of the study

All measures of consensus were investigated through more than one question which enabled critical evaluation of outliers on one measure against the position in the other measures.

These built-in checks and balances enabled multiple measures to be cross analysed and served to negate the need for a third questionnaire.

The relatively large and homogenous participant group strengthens the reliability of the findings (Day and Bobeva 2005; Nasa, Jain and Juneja 2021).

The blinded nature of the questionnaires prevented any researcher or participant bias. The initial online QP aggregate analysis of all quantitative data provided an additional level of blinding as the researcher did not have to interrogate each response sheet individually. This level of blinding also promoted honesty in answers where participants may have been reluctant to acknowledge lack of knowledge in person.

5.14.1 Delphi Q1

The emphasis on anonymity as a virtue could also be considered detrimental to the personal feedback of a Delphi process. In this research feedback limited each participant to only their own answers in comparison to the aggregate at the time of their participation, rather than to a final full participant aggregate. As part of the Q2 question structure participants received feedback on aggregate analysis, but this could not be personalised to their own answer from Q1. They could however consult their Q1 answer sheet and SLR (Appendix 7) for reconsideration of their Q1 answers during answering of Q2.

Although this can be seen as a limitation in a Delphi study, strict anonymity was necessary to allow for possible unpopular opinions and obtain the number of participants this study received.

5.14.2 Delphi Q2

The design of questions 20 to 35 (the modality dependency questions) lent itself to selection bias during average importance ranking analysis. A very low importance modality with only one selection would necessarily be listed as an average importance of 1, although when considering that only one out of 34 participants made the selection the modality would have a selection frequency of 3.1%. This was overcome by doing multiple backward and forward analyses of the data as selection frequency, participant frequency, importance rating, weighted rank order, as well as Pareto chart and quartile analysis.

This was a highly time-consuming process; however, it did yield robust results that could be used to structure a modality dependency affinity diagram upon which to base the learning framework.

5.15 Limitations

5.15.1 Demographic questions

Participants were asked about post qualification experience and involvement in student training, however no information regarding the participants' training environment was provided. It would have been interesting to test the influence of the training environment between academic units and private practitioners in relation to some of the ambiguous outcomes. In particular the inclusion and outcome level selections of EMG and IOM modalities may relate to personal training experiences.

5.15.2 Q1 modality list

Limitations of the Q1 modality list were the absence of paediatric NCS, EEG monitoring during carotid endarterectomy procedures, and other procedures from the original 1988 scope of practice (Figure 2.1) such as electroretinograms. These are modalities that are practiced and taught in isolated units, however, were not included in any of the training documents perused.

5.16 Areas for future research

The scope of this research was to determine the foundational modalities required for graduates to integrate into the private practice industry and investigate the related skills and attributes needed to obtain this goal.

Further future research into curriculum design, WIL presentation, and standardised practical competency and proficiency testing rubrics are needed to achieve the goal of industry-ready graduates.

Additional needs assessment and course development are needed for the advanced CN modalities which are not included in this proposed essential undergraduate WIL content framework, but that form part of the current and historical scope of practice documents.

It is hoped that this work will contribute to the review of category specific WIL frameworks for the other six CT specialist categories.

CHAPTER 6: CONCLUSION

All aims and objectives of the research were achieved. This research showed that there is good industry agreement on outcome needs for a four-year undergraduate degree. This research also showed that there is a good interconnectedness between all the essential modalities, and I am hopeful that the proposed framework will serve to enable WIL units to achieve the required outcomes for our CTs and KT-Ss and the CN profession.

6.1 Work-integrated learning content framework

Group consensus on outcome year was competency- and proficiency-related rather than modality-specific. Using the method described in Chapter 3 Section 3.15.3, a driver diagram was used to construct a WIL content framework for the full BHS course rather than per year of study. This framework is presented in Figure 6.1.

The driver columns are derived from the levels of the modality learning dependency affinity diagram (Figure 5.1). The driver diagram is read vertically from left to right with the highest level of the affinity diagram forming the first driver level. The driver levels are vertically separated by the embedded skills and attributes related to mastering the preceding driver modalities. Skills and attributes were grouped according to the thematic analysis categories (Human 1996).

As reported in Chapter 4 all embedded skills and attributes were highly affiliated with all modalities. Therefore, attributes listed in each level of the framework show the level at which the skill must reach the final level of mastering rather than where teaching originates.

Outcome	Primary Driver	Skills and Attributes	Secondary Drivers	Skills and Attributes	Tertiary Drivers	Skills and Attributes	Quaternary Drivers	Skills and Attributes
Bachelor of Health Science in Clinical Technology: Neurophysiology	Routine Electroencephalography	**Quality Control**	Flash Visual Evoked Potentials	**Quality Control**	Pattern Reversal Visual Evoked potential	**Quality Control**		
		Troubleshooting: physiologic patient-related factors		Replication of waveforms		Adjust to new research and practice standards		
		Clean electrode sites: Impedances		**Performance**		**Performance**		
		Aseptic Infection control		Recognise and capture Waveforms		Assess Visual Acuity		
		Accurate distance measurement						
		Annotations	Brainstem Auditory Evoked Potentials	**Quality Control**				
		Electrical safety		Repeatability/ Reproducibility of serial tests				
		Performance		**Analysis**				
		Equipment machine knowledge/ setting manipulation		Identifying abnormal				
		Surface Electrode Placement Recording – accurate and technically correct		**Communication**	Somatosensory Evoked Potentials	**Performance**		
		Understand/ choose/ modify montages		Communicate with hearing disability		Correct stimulation choice		

Outcome	Primary Driver	Skills and Attributes	Secondary Drivers	Skills and Attributes	Tertiary Drivers	Skills and Attributes	Quaternary Drivers	Skills and Attributes
		Surface RECORDING techniques				Personal		
		Communication				Critical thinking		
		Protocol and procedure development	Nerve conduction Studie	Quality Control				
		Data collection and management		Troubleshooting and correction: technical problems				
		Plan ahead: Be prepared		Analysis				
		Personal		Measurement of wave forms/ calculations				
		Professionalism/ work ethic		Integrate results from multiple tests	Electromyography	Performance		
		Enthusiasm		Apply Anatomy		Needle Electrode Placement Recording – setup accurate and technically correct		
		Be receptive		Apply Pathophysiology		Needle Electrode Placement Stimulating – setup accurate and technically correct		

Outcome	Primary Driver	Skills and Attributes	Secondary Drivers	Skills and Attributes	Tertiary Drivers	Skills and Attributes	Quaternary Drivers	Skills and Attributes
		Adaptability		**Performance**		Needle RECORDING techniques		
		Recognise personal limits and obtain assistance		Surface Electrode Placement Stimulating – setup accurate and technically correct		Needle STIMULATION techniques		
		Confidence without Arrogance		Surface STIMULATION techniques				
		Work with different age groups		**Personal**				
		Work with different personalities (patients and colleagues)		Perform under pressure				
		Stay calm		Steady hands/ Dexterous/ Fine motor control				
				Experiencing the test procedure to understand patient experience				
			Beds ide EEG	**Quality Control**	Neon atal EEG	**Quality Control**	Conti nuou s ICU EEG	**Quality Control**
				Apply Protocol				

Outcome	Primary Driver	Skills and Attributes	Secondary Drivers	Skills and Attributes	Tertiary Drivers	Skills and Attributes	Quaternary Drivers	Skills and Attributes
				Maintain minimum standards		Artefact Correction: **Physiologic**		Correction of ICU Specific Artefact
				Analysis skills		Artefact Correction: Non-physiologic		ICU: Set-up of equipment neat and out of the way
				Identifying Normal		Sterile Infection control		**Analysis skills**
				Interpret and report: include recording limitations		Care of electrode site		Indication of drugs
				Apply Physiology				**Performance**
				Effect of Medication/Drugs				Manage side effects to testing or treatment
				Maintain records/ documentation of procedures				Work with Collodion or similar
				Identifying sleep features				Ambulatory recording
								Communication
								ICU protocols – work with ICU staff
						Personal	Surface Electrode Long-term	**Quality Control**
				Performance		Teamwork		Measure 10-20 positions

Outcome	Primary Driver	Skills and Attributes	Secondary Drivers	Skills and Attributes	Tertiary Drivers	Skills and Attributes	Quaternary Drivers	Skills and Attributes
				Manage patient events/emergencies				**Analysis skills**
				Adjust protocol to obtain relevant information				Correlating recording with video
				History/ pre-test evaluation				**Performance**
				Patient Preparation: (safe patient manipulation/ correct positioning/ dignity/ mobility/ comfort)				Setup video recording
								Communication
				Personal Positioning: (comfortable and stable)				Theatre protocols – work with Theatre staff
				Appropriate Activation procedures	Polysomnography	**Analysis skills**	Multiple Sleep Latency Test	**Quality Control**
				Communication		Diagnosis / Classify disease		Manage/control SLEEP during recording
				Communicate with staff: Doctors, nurses, and colleagues		Understand treatment options		
				Bedside manner: Patient interaction/ communication		**Performance**		

Outcome	Primary Driver	Skills and Attributes	Secondary Drivers	Skills and Attributes	Tertiary Drivers	Skills and Attributes	Quaternary Drivers	Skills and Attributes
				Obtain cooperation/ all ages / explain procedure		Manage sp02 and intubation		
				Calibration and maintenance and testing of equipment		**Personal**		
				Self-development – stay up to date with developments		Ability to concentrate for extended periods of time		
				Personal		Maintain focus		
				Management of difficult patients		Time management		
				Listening		Use organised methods		

Figure 6.1: A work integrated learning content framework for clinical neurophysiology technology in South African universities of technology

6.2 Recommendations for current training

6.2.1 Recommendations to universities of technology

In line with the findings of this study and the historic focus on specialised organ system knowledge, it is recommended that the UoTs reinstate category-specific specialised anatomy and physiology TLA at the third-year level. This will also be in line with international training and examination guidelines (Tsuchida 2016; Morris 2017; Association of Neurophysiological Technologists of Australia Inc 2019; American Academy of Neurology *et al.* 2020c, 2022c, 2022a; American Society of Electroneurodiagnostic Technologists [ASET] 2021; Joint Royal Colleges of Physicians Training Board 2021; ABRET 2022c, 2022e; AETC 2023; Middlesex University London 2023).

Additionally, it is strongly suggested that UoTs include practical and theoretical outcome examinations on all procedures before conveying qualifications to graduates.

It is important that UoTs carefully evaluate the neurophysiology units they place students in to ensure that students will be exposed to all the requisite modalities, at the correct outcome level, especially where one piece of equipment is used for multiple modalities.

It is important that when promoting neurophysiology units for training accreditation UoTs must place greater importance on all procedures being taught equally during accreditation applications.

6.2.2 Recommendations to the regulatory body

Accreditation of training facilities are not a unilateral or purely administrative process and the HPCSA accreditation inspections should include proof of such training being offered according to internationally recognised minimum practice standard guidelines. As a regulator it is suggested that HPCSA registration should require proof of competency in practising the procedures included in the professional scope of practice of independent practioners' training. These last two points apply to all modalities, but more so to routine EEG as this is the foundation of all training, and not only needle examinations, but especially needle investigations, as this forms the basis of advanced practices such as IONM.

6.2.3 Combined responsibility

Lastly, with the decreased clinical training time, both the universities and HPCSA confirm that a candidate has completed the mandatory 3 840 hours within an accredited specialist category training unit. Documented clinical training hours should, as stated in the 1995 registration rules, pertain only to the specialist category training (South Africa 1995), not general non-category specific practical instruction during on-campus instruction.

In the end it is this practical training time that allow our graduates to gain category specific training and most of all experience. It is this experience that will afford them the confidence to become competent independent clinical neurophysiologists.

However, the needs of our patients must not be overlooked by focusing just on completion of experiential training hours but kept sacred by also performing industry and internationally benchmarked standardised proficiency examinations.

It is the combined responsibility of the educator and the regulator to ensure that new graduates, and therefore new practitioners, are fully able to safely provide patient care.

6.3 A proposed way forward

As mentioned in Section 5.16 additional research is required to develop a TLA curriculum supportive of the current WIL content framework. It is pertinent to keep in mind that this current framework only represents industry requirements, and although it does provide guidance into the order of mastering of modalities it does not include teaching or assessment methods.

Implementation of this modality driven framework will need the support of a structured category specific curriculum targeting all the embedded knowledge and practical skills required for mastering each of the different modalities. Such a curriculum will need to incorporate various WIL pedagogies to integrate teaching, learning and assessment of both the theory and practical skills.

Special attention should also be given to early detection and development of the personal attributes and skills – soft skills – required of our graduates as reported in Section 4.16 and discussed in Section 5.6.

As regulator of the profession, and administrator of the scope of practice and profession, the HPCSA and the universities, as conveyors of qualifications, will need to endeavour in unison to standardise graduate outcomes for the wellbeing of our patients and the future of our profession.

6.4 Final words

In the words of Dr William James Mayo, M.D.: “The best interest of the patient is the only interest to be considered, and in order that the sick may have the benefit of advancing knowledge, a union of forces is necessary” Beck (2000).

It is my hope that this study will once again lead to a lockstep between industry and UoTs for the betterment of our training and ultimately to better serve our patients through well-educated graduates.

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APPENDICES

Appendix 1: Ethics approval

Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375
Email: lavishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

13 May 2021

Ms C Van Der Walt
72 Winifred Drive
St. Winifreds
Kingsburgh
4126

Dear Ms Van Der Walt

A Work-Integrated Learning Framework in Clinical Neurophysiology in South African Universities of Technology
Ethics Clearance Number: IREC 014/21

The Institutional Research Ethics Committee acknowledges receipt of your gatekeeper permission letter.

Please note that FULL APPROVAL is granted to your research proposal. You may proceed with data collection.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC Standard Operating Procedures (SOP's).

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

[redacted]

Dr K Padayachy
Deputy Chairperson: IREC

Appendix 2: Gatekeeper letter from CNSSA

CNSSA

CLINICAL NEUROPHYSIOLOGY SOCIETY OF SOUTH AFRICA

Christelle van der Walt: President
(+27)798556068
Elené Ackermann: Treasurer
(+27)823882926

Paul Blom: Secretary
(+27)0733022890
Peet Vermaak: Immediate Past President
(+27)827739390

To whom it concerns

26/04/2021

I, Elené Ackermann, treasurer of Clinical Neurophysiology Society of South Africa, hereby give student, Christelle van der Walt, permission to do her Master of Health Science research using our society's existing database. The only condition is that information obtained and used in the study must remain confidential.

Regards

[redacted]

Elené Ackermann

Appendix 3: E-mail invitations

3.1 E-mail invitation for distribution list

Good day,

I would like to invite you to participate in the second round of my research as a member of a panel of experts in a Delphi survey study.

The purpose of this study is to determine the required graduate competencies, and minimum clinical skills that Bachelor of Health Science (BHS) Clinical Technology (Neurophysiology) graduates are expected to acquire during the 3rd and 4th year of their Work-Integrated Learning (WIL) specialisation.

LETTER OF INFORMATION

Title of the Research Study: A Work-Integrated Learning Framework in Clinical Neurophysiology in South African Universities of Technology

Principal Investigator/researcher: Christelle van der Walt, B Tech Clin Tech (Neuro)

Qualification: Masters of Health Sciences in Clinical Technology Neurophysiology

Co-Investigator/s/supervisor/s: Dr Penelope Orton, PhD; Dr Suzaan Marais, MBChB, FC Neurology, PhD; Dr Rosaley Prakaschandra, PhD;

A Delphi study is a research tool that brings together a panel of experts (called panellists) to explore ideas or problems creatively and using the whole group's combined knowledge to find consensus and its strength, but also to bring convergence of opinions regarding the topic under investigation.

If you consent to participate, your identity will be kept confidential and you will be included in either two or three rounds of a Delphi survey, taking approximately one hour per round. Each round will have a return time of one week, with a second week between rounds. It is hoped if you consent to participate that you will actively participate in each round and reply within four days of being asked to evaluate each round of the Delphi instrument.

The initial Delphi survey instrument contains a list of current, frequently practiced test modalities. (E.g. Routine EEG and Nerve Conduction Studies etc.).
You will be asked to list the ten most important modalities related to graduate skills, including prerequisite or embedded skills and attributes, that you believe BHS graduates must achieve during the third and fourth level of WIL instruction.
You can also add any omitted test modality that you regard as a minimum requirement by providing the same modality related information.

After all the panellists have completed each survey round, the responses will be collated, and the results will be shared with the panellists as part of the next round.
For the second and third rounds additional new statements from the panel will be shared and all panellists will be asked to comment on the requisite skills and education requirements for competency.

Each round will consist of an online Delphi survey that you will be able to access privately and complete at your convenience.

Participation is completely voluntary, and no monetary remuneration or other incentives will be provided. A panellist may at any time withdraw from participation in further rounds and no explanation will be required. You may also be removed from subsequent rounds through non-response to the current round within the one-week period allowed for completion. The only cost of participation to you will be investment of your time to complete the bi-weekly Delphi surveys.

Potential benefit to the profession is a more focused and standardised WIL specialisation for increased competence of graduates with a nationally comparable skill set.

After consenting to participation, the identities of participants will be confidential, and identities of panellist will not be linked to their responses.

This study does not carry risk of research related injury as it is an anonymous online questionnaire survey.

If you are willing to participate on the panel of experts, please carefully read the consent. If you accept participation, please follow the link to the online questionnaire included at the end of the consent document. Alternatively, you may contact me per email at christellev@dut.ac.za for a link to the questionnaire. Completion of the questionnaire will indicate acceptance of the contents of the consent letter.

The success of this research is dependent on obtaining as many different Clinical Neurophysiologist as possible to participate therefore you may forward this invitation to any Clinical Neurophysiologist you think may be interested in participation.

I do apologize if you may have received duplicate invitations.

Please follow this link to the informed consent page and to start the questionnaire. <SURVEY_LINK>

Kind Regards,

Ms. C van der Walt

Persons to Contact in the Event of Any Problems or Queries:

Please contact the researcher Christelle van der Walt 0798556869, my supervisor, Dr P Orton pennyo@dut.ac.za or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the DVC: Research, Innovation and Engagement Prof S Moyo on 031 373 2577 or moyos@dut.ac.za.

3.2 Reminder invitation for un-started invitations

Good day,

I still need a few completed answer sets in Round 2 of my research to compile a balanced view of our profession's needs.
If you have not had opportunity to yet, I would like to re-invite you to participate in my research as a member of a panel of experts in a Delphi survey study.

The purpose of this study is to determine the required graduate competencies, and minimum clinical skills that Bachelor of Health Science (BHS) Clinical Technology (Neurophysiology) graduates are expected to acquire during the 3rd and 4th year of their Work-Integrated Learning (WIL) specialisation.

SAVE AND CONTINUE LINK EMAIL

*Participant information letter was attached as per first invitation.

3.3 Completion of Questionnaire email

Subject: Thanks for your time,

Thank you for participating in my research as an expert panellist. You may expect an invitation to the next round of my research soon.

I am including a copy of your response for your records. You may also like to review your answers upon receiving the next round questionnaire which will ask you to rate the importance of group opinions found during round one.

Kind Regards,

Christelle van der Walt

christellev@dut.ac.za

Attachment: Personal survey response (Appendix 4)

3.4 Saved incomplete questionnaire link

Subject: Your Saved Survey

Hello,

We have a partial response saved for you. To start the survey from where you saved, please click on the link below:

Start Saved Survey

Thank you.

3.5 Terminated questionnaire message

Thank you for your interest in the second round of my research.
Your profile does not fit the criteria for this study.

Thank you for your time.

Appendix 4: Respondent email survey report

Full report is available on request. Example provided using author's own test response report.

Thanks for your time

Christelle van der Walt <christellev@dut.ac.za>

Thu 2021/05/27 04:50

To:chrisvdwalt <chrisvdwalt@gmail.com>

Thank you for participating in my research as an expert panelist. You may expect an invitation to the next round of my research soon.

I am including a copy of your response for your records. You may also like to review your answers upon receiving the next round questionnaire which will ask you to rate the importance of group opinions found during round one.

Kind Regards,
Christelle van der Walt
christellev@dut.ac.za

Response ID: 45984922

* Are you registered with the Health Professions Council of South Africa as a Clinical Technologist in the specialist category **Neurophysiology**?

» Yes

Please identify your post-training practice experience:

» Private Practice Only

---

*
Please indicate your current Health Professions Council of South Africa level of registration in Clinical Neurophysiology:

» Private Practice

---

* Please indicate your current highest level of qualification in Clinical Technology recognised by the Health Professions Council of South Africa:

» MHSc

---

*
Please identify your gender

» Female

---

* Please select **up to ten (10) Clinical Neurophysiology Modalities** you consider **ESSENTIAL** to include in the BHS Clinical Technology Neurophysiology Work Integrated Learning program:

» Brainstem Auditory Evoked Potentials

» Routine Electroencephalography

» Your own choice of additional modality aft

Appendix 5: Questionnaire 1

This section contains sample extracts of the questionnaire to demonstrate each question type. For access to the full questionnaire please access the following link: https://dut.questionpro.com/Questionnaire1

5.1 Welcome to the Round 1 Delphi Questionnaire:

Welcome to the Round 1 Delphi Questionnaire:

You have accepted to participate as an expert panelist in Clinical Neurophysiology as part of the research: **A Work-Integrated Learning Framework in Clinical Neurophysiology in South African Universities of Technology.**

It is very important for us to learn your expert opinions.

In this first survey you will have the opportunity to identify the essential clinical neurophysiology testing modalities graduates of the Bachelor of Health Science in Clinical Technology degree must master during their work integrated learning training.
You will also be asked to identify the requisite skills and graduate attributes related to each of the modalities you have identified as essential.

NOTE 1: Please restrict your answers to **ONLY third- and fourth-year work integrated learning** specialisation in Clinical Neurophysiology.

NOTE 2: Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. You can withdraw from the survey at any point. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential.

If you have questions at any time about the survey or the procedures, you may contact Christelle van der Walt at 0798556869 or by email at christellev@dut.ac.za.

Thank you very much for your time and support.

By clicking on the START button you will be taken to the consent page.

5.2 Statement of Agreement to Participate in the Research Study:

CONSENT STATEMENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Christelle van der Walt, about the nature, conduct, benefits and risks of this study. Research Ethics Clearance Number: IREC 014/2021.
- I have also received, read and understood the above written (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my gender and level of registration will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and continued participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

Completion of the questionnaire will indicate your acceptance of the contents of this consent statement.

Please start with the survey now by selecting "I Agree" and clicking on the NEXT button below.

☐ I Agree

5.3 Inclusion and demographic questions

* Are you registered with the Health Professions Council of South Africa as a Clinical Technologist in the specialist category Neurophysiology?

- ○ Yes
- ○ No

Please identify your post-training practice experience:

- ☐ Private Practice Only
- ☐ Public (State) Practice Only
- ☐ Combined Private Practice and Public (State) Practice

* Please indicate your current Health Professions Council of South Africa level of registration in Clinical Neurophysiology:

- ○ Independent Practice
- ○ Private Practice
- ○ Supervised Practice
- ○ Student
- ○ Other

* Please indicate your current highest level of qualification in Clinical Technology recognised by the Health Professions Council of South Africa:

- ○ National Diploma Pre 2001
- ○ National Diploma Post 2001
- ○ B Tech
- ○ M Tech
- ○ D Tech
- ○ BHSc
- ○ MHSc
- ○ Other

* Please identify your gender

- ☐ Female
- ☐ Male
- ☐ Prefer not to say

5.4 Essential outcome modalities

ESSENTIAL OUTCOME MODALITIES

You will now be presented with list of work integrated learning outcome modalities as assembled from previous and current South African Clinical Neurophysiology training documents.

You are granted the opportunity to select a maximum of TEN outcome modalities that you consider **ESSENTIAL** for graduates of the Bachelor of Health Science in Clinical Neurophysiology degree program to master for successful integration in to the Private Practice industry environment.

You may also add an additional outcome modality that is not part of the list, but that you consider **ESSENTIAL**. Please remember your choice of additional modality as you will be asked to provide further information later in the questionnaire.

* **Please select up to ten (10) Clinical Neurophysiology Modalities you consider ESSENTIAL to include in the BHS Clinical Technology Neurophysiology Work Integrated Learning program:**

- ☐ Assist with Electromyography
- ☐ Brainstem Auditory Evoked Potentials
- ☐ Bedside Electroencephalography
- ☐ Continuous ICU Electroencephalography
- ☐ Cortical Brain Mapping
- ☐ Deep Brain Stimulation
- ☐ Drug Administration and management of side effects
- ☐ Flash Visual Evoked Potentials
- ☐ Intraoperative neuro-monitoring using multi-modality evoked potentials
- ☐ Long-term EEG video monitoring using **surface AND grid** recordings (Subdural monitoring)
- ☐ Long-term EEG video monitoring using **ONLY surface** electrodes
- ☐ Maintenance of Wakefulness Test
- ☐ Memory Testing
- ☐ Multiple Sleep Latency Test
- ☐ Needle Electromyography
- ☐ Neonatal Electroencephalography
- ☐ Nerve Conduction Studies
- ☐ Pattern Reversal Visual Evoked Potentials
- ☐ Peripheral Nerve and Muscle Ultrasonography
- ☐ Polysomnography

5.5 Skills ability level

SKILLS ABILITY LEVEL

On the next pages you will be asked to indicate the **level of skills ability** you believe students must master during the **work integrated learning period** relevant to each of your chosen outcome modalities.

You will be individually presented with each of the modalities you have identified as essential to be included in the Bachelor of Health Science in Clinical Technology degree in Neurophysiology that students must master during their **work integrated learning training**.

Please indicate the skills ability level you consider essential for our graduates to achieve in "Assist with Electromyography":

- ◯ Perform Recording
- ◯ Analyse Results
- ◯ Technical Report (Description of findings)
- ◯ Interpretative Report (Identification of abnormal findings)
- ◯ Clinical Diagnostic Report (Providing a clinical diagnosis)
- ◯ Other

This question repeated for each of the selections made during the previous selection question.

5.6 Embedded practical skills contributions

PRACTICAL SKILLS
On the next pages you will be asked to contribute **up to five (5) prerequisite or embedded PRACTICAL skills** you believe students must be taught during the **work integrated learning period** to master each relevant outcome modality. You will again be individually presented with each of the modalities you have identified as essential to be included in the Bachelor of Health Science in Clinical Technology degree in Neurophysiology that students must master during their **work integrated learning training**.

* Please contribute up to five (5) prerequisite or embedded PRACTICAL SKILLS you believe students must be taught during the work integrated learning period to master the outcome "Assist with Electromyography":

Practical skill ONE

Practical skill TWO

Practical skill THREE

Practical skill FOUR

Practical skill FIVE

This question repeated for each of the selections made during the modality selection question.

5.7 Theoretical skills and knowledge contributions

THEORETICAL SKILLS OR KNOWLEDGE

On the next pages you will be asked to contribute **up to five (5) prerequisite or embedded THEORETICAL SKILLS OR KNOWLEDGE** you believe students must be taught during the **work integrated learning** period to master each relevant outcome modality.

You will again be individually presented with each of the modalities you have identified as essential to be included in the Bachelor of Health Science in Clinical Technology degree in Neurophysiology and that students must master during their **work integrated learning training**.

* Please contribute up to five (5) prerequisite or embedded THEORETICAL SKILLS OR KNOWLEDGE you believe students must be taught during the work integrated learning period to master "Assisting with Electromyography":

Theory skill ONE

Theory skill TWO

Theory skill THREE

Theory skill FOUR

Theory skill FIVE

This question repeated for each of the selections made during the modality selection question.

5.8 End message

Thank you for participating as a panelist in the first round of my research.
You will receive the second round questionnaire based on the panel's responses to provide your further expert opinion at the address you provided.

On the next page you will be presented with a report indicating your answers compared to the current overall response results.

Only you have access to this report.

Please export, save, and retain this report. You may need to review your answer choices while providing ratings in the Round Two questionnaire.

FINISH

The next screen displayed the SpotLight® report providing personal feedback in comparison to the aggregate group response (Appendix 7) for download. Participants also received an email with their full response report (Appendix 4).

Appendix 6: Questionnaire 2

This section contains sample extracts of the questionnaire two. to demonstrate each question type. For access to the full questionnaire please access the following link: https://dut.questionpro.com/Questionnaire2

Questions with a red * were required with forced validation settings.

6.1 Welcome to the Round 2 Delphi Questionnaire:

Wlcome to the Round 2 Delphi Questionnaire:

Participant letter of information:

You are being invited to participate as an expert panellist in Clinical Neurophysiology as part of the research: **A Work-Integrated Learning Framework in Clinical Neurophysiology in South African Universities of Technology.**

It is very important for us to learn your expert opinions.

In this **second survey** you will be asked to score or rank or order information processed from the first questionnaire.

You will have the opportunity to select the most important prerequisite or dependent test modalities for each of the modalities identified as essential for graduates to master.
You will also have the opportunity to select the skills required to master each test modality as submitted during the first-round questionnaire.

NOTE 1: Please restrict your answers to **ONLY third- and fourth-year work integrated learning** specialisation in Clinical Neurophysiology.

NOTE 2: Your participation in this study is completely voluntary. There are no foreseeable risks associated with this project. You can withdraw from the survey at any point. Your survey responses will be strictly confidential and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential.

If you have questions at any time about the survey or the procedures, you may contact Christelle van der Walt at 0798556869 or by email at christellev@dut.ac.za.

Thank you very much for your time and support.

By clicking on the **START** button you will be taken to the consent page.

Start

Save & Continue Later

6.2 Consent Statement

Clinical Neurophysiology Education in South Africa Round Two

CONSENT STATEMENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, Christelle van der Walt, about the nature, conduct, benefits and risks of this study. Research Ethics Clearance Number: IREC 014/2021.
- I have also received, read and understood the above written (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my gender and level of registration will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and continued participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

Please indicate your acceptance of the contents of this consent statement by selecting "**I Agree**" below.

Please start with the survey now by clicking on the **NEXT** button below.

☐ I Agree

< Next Save & Continue Later

6.3 Inclusion criteria

* Are you registered with the Health Professions Council of South Africa as a Clinical Technologist in the specialist category **Neurophysiology**?

Yes No

< Next Save & Continue Later

* Please indicate your current Health Professions Council of South Africa level of registration in Clinical Neurophysiology:
Select One

Student Private Practice Independent Practice Supervised Practice

< Next Save & Continue Later

If answer is No or Student the questionnaire terminates to thank you message.

Thank you for your interest in the second round of my research.
Your profile does not fit the criteria for this study.

Thank you for your time

6.4 Demographic questions

* Please indicate your current highest level of qualification in Clinical Technology recognised by the Health Professions Council of South Africa:
Select One

-- Select --

- -- Select --
- B Tech
- BHSc
- MHSc
- D Tech
- M Tech
- National Diploma Post 2001
- National Diploma Pre 2001
- Other

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Questions marked with a * are required

* Please identify your post-training practice experience:
Select One

☐ Government Service Only ☐ Private Practice Only ☐ Combined Private Practice and Government Service

< Next Save & Continue Later

* How many years of post-qualification experience do you have?

< Next Save & Continue Later

(Numeric input)

* Are you currently or previously involved in student practical work integrated learning training?

◯ Yes - currently ◯ No - never in the past or currently ◯ Yes - previously, but not at present

< **Next** Save & Continue Later

Please identify your gender

☐ Female ☐ Male ☐ Prefer not to say

< **Next** Save & Continue Later

Please use the slider to indicate how many years work integrated learning did your first qualification in Clinical Neurophysiology require (N Dip or BHSc)

	0	3
Year of Work Integrated Learning		

< **Next** Save & Continue Later

6.5 Question block one: Questions originating from Questionnaire One

Please answer the following questions that arose from comments in Questionnaire One:

< Next Save & Continue Later

Do you consider **Flash/Goggle VEP** an essential testing modality that students in the BHSc course must master prior to graduation?

- ○ Yes, it is essential for BHSc graduates to master
- ○ No, it is unnecessary for BHSc graduates to master

< Next Save & Continue Later

Do you consider *Non-invasive Ventilation* or *Positive Airway Pressure* treatment a **separate modality** or **subordinate skill** included in the modality of **Polysomnography**?

- ○ PAP is a Polysomnography skill
- ○ PAP is a separate additional modality

< Next Save & Continue Later

In regards to Routine Neurological Brainstem Auditory Evoked Potential testing (Neurological ABR/BAEP /BAER):

What stimulus is consider sufficient or **essential** for routine testing for graduates **to master during the undergraduate WIL**?

- ○ Graduates need to know Routine testing with **Click Responses and Tone Burst Responses**
- ○ Graduates only need to know Routine testing with **Tone Burst Responses**
- ○ Graduates only need to know Routine testing with **Click Responses**

< Next Save & Continue Later

6.6 Question block two: Essential Outcome Modalities

ESSENTIAL OUTCOME MODALITIES

15 Testing modalities were identified as **ESSENTIAL outcomes** through Questionnaire One and Positive airway pressure therapy (PAP) was added to the list.

We must now determine the order of importance of accommodating these 16 modalities in the **work integrated learning (WIL)** period.

Please keep in mind that the **work-integrated learning period is 18 - 24 months**.

Keep your answers limited to what is **ESSENTIAL** for graduates of the Bachelor of Health Science in Clinical Neurophysiology degree program **to master during the WIL period ONLY**.

You may OMIT any modality that you believe may or should be excluded from undergraduate WIL.

< Next Save & Continue Later |

Please rank the modalities you consider Essential Outcome modalities for undergraduate **work-integrated learning**.

Please drag the modalities into **ORDER** of PRIORITY for learning.

START with the modality that should be taught first on **TOP**.

This order applies to the total work-integrated learning period:

< **Next** Save & Continue Later

Please drag the modalities listed on the left to form a new list on the right to rank the modalities **in order of learning**.

(If you consider any listed modality as Non-Essential please OMIT the modality in your ranking)

Drag your choices here to rank them

- Brainstem Auditory Evoked Potentials
- Routine Electroencephalography
- Long-term EEG video monitoring using **ONLY surface electrodes**
- Nerve Conduction Studies
- Multiple Sleep Latency Test
- Continuous ICU Electroencephalography
- Long-term EEG video monitoring using grid recordings **(Subdural monitoring)**
- Pattern Reversal Visual Evoked Potentials
- Somatosensory Evoked Potentials
- Flash Visual Evoked Potentials
- Needle Electromyography
- Positive Airway Pressure Therapy
- Neonatal Electroencephalography
- Bedside Electroencephalography
- Polysomnography
- Intraoperative Neuro-monitoring using Multi-modality Evoked Potentials

< **Next** Save & Continue Later

6.7 Question block three: Prerequisite and modalities dependent on prior learning

PREREQUISITE AND MODALITIES DEPENDENT ON PRIOR LEARNING

Next you will be presented with **INDIVIDUAL** modalities identified for inclusion in the work integrated learning period.

For each modality please select ONLY related modalities in the left column and drag to the selection boxes on the right to categorise as either **prerequisite** or **dependent.**

Using READING as an example: if **reading** is the skill in question, a prerequisite skill may be knowing the **alphabet**, and a skill depended on prior learning of *reading* could be **writing**

*Therefore, the **alphabet** is a **prerequisite** skill and must be mastered prior to learning **reading**, but **writing** may be a skill **dependent** on mastering the skill of **reading**.

NOTE: Please list **prerequisite** modalities in order of teaching order/introduction **priority** from most important to least important modality.
*Please answer all modalities

< Next Save & Continue Later

Please select ONLY the **prerequisite** and **dependent** modalities from the list on the left and categorise by dragging to the selection boxes on the right.

(If there is no prerequisite or dependent modalities please continue to the next modality)

Drag your cards here to categorize them.

	Prerequisite and must be mastered first before learning Bedside Electroencephalography *(List in order of most priority)*	**Dependent** on prior mastering of Bedside EEG *(Can only be taught after)* 2
Needle Electromyography	1 Long-term EEG video monitoring using **ONLY surface electrodes**	1 Nerve Conduction Studies
Brainstem Auditory Evoked Potentials	2 Continuous ICU Electroencephalography	2 Somatosensory Evoked Potentials
Long-term EEG video monitoring using grid recordings **(Subdural monitoring)**		
Flash Visual Evoked Potentials		
Multiple Sleep Latency Test		
Positive Airway Pressure Therapy		
Neonatal Electroencephalography		
Polysomnography		
Routine Electroencephalography		
Pattern Reversal Visual Evoked Potentials		

< **Next** Save & Continue Later

This question repeats for all modalities in alphabetical order.

6.8 Question block four: Graduate Outcome Skills Levels

GRADUATE OUTCOME SKILLS LEVELS

Next you will be presented with graduation level outcomes per modality.

The **BOLD TEXT** next to the modality name is the **group** selection **result** from Questionnaire One.

Please do ONE of the following:

1: If you **agree** with the outcome level please **indicate** your **agreement by selecting the same outcome level** as is shown in **BOLD** next to choice the modality name.
OR
2: If you do not agree please select an the outcome level you believe graduates must **achieve at** the **end** of their **WIL** period.
OR
3: Select **N/A** if you believe any of the **modalities** may or should be **EXCLUDED in undergraduate WIL.**

NOTE: Please keep answers limited to the WIL period of 18-20 months.

Please indicate the final level of skill a student must master at the end of their WIL for graduation:

Select **N/A** if you believe any of the modalities may or should be **EXCLUDED** in undergraduate WIL.

Indicate your **agreement** by **selecting the same outcome level as is shown in BOLD**
Select One

	ONLY PERFORM Recording	**DESCRIBE report** Perform, Analyse and write a technical **descriptive report** (describe the findings in comparison to known patterns or values)	**INTERPRETATIVE report** Perform, Analyse and write an **interpretive report** (Classify results according to pathological implication without clinical correlation)	**CLINICAL correlative report** Perform, Analyse and write a **clinical correlative report** (Suggest a clinical diagnosis or make recommendations)	**N/A**
Flash Visual Evoked Potentials **(INTERPRETATIVE)**	○	○	○	○	○
Needle Electromyography **(PERFORM)**	○	○	○	○	○
Continuous ICU Electroencephalography **(INTERPRETATIVE)**	○	○	○	○	○
Bedside Electroencephalography **(INTERPRETATIVE)**	○	○	○	○	○
Multiple Sleep Latency Test **(CLINICAL)**	○	○	○	○	○

This question repeated until all modalities were evaluated.

6.9 Block five: Skills Outcome Levels per year of study and minimum procedure numbers

SKILLS OUTCOME LEVELS

You will be presented with options for third and fourth year study outcome practice levels per modality.

Please do **ALL** of the following:

1: Indicate **at what year of WIL training** (third or fourth year of study) you believe a student should achieve **basic practical competency**.
AND
2: Indicate **at what year full proficiency** should be attained (third or fourth year of study).
AND
3: Indicate the **minimum number of procedures** necessary **for** to attain full outcome **proficiency**.

Select **N/A** in the drop down selections if you believe the modality may or should be **EXCLUDED from undergraduate WIL.**

NOTE: Please keep in mind that the WIL period is only 18-20 months.

For each of the listed testing modalities:

1:Please select the **year of study** a student must pass **basic practical competency**
AND
2:Please select the **year of study** a student must show **full practical and analytical proficiency** at final graduation level

(Please mark as N/A if COMPETENCY or graduate PROFICIENCY cannot be achieved during UNDERGRADUATE third or fourth year study level)

3:Please indicated the **minimum number of procedures** that must be completed for full **outcome proficiency**

	Study year for achievement of **basic practical competency** in performing	Study year for achievement of **full proficiency** in analysis and reporting	Minimum number of procedures
Bedside Electroencephalography	N/A	-- Select --	
Brainstem Auditory Evoked Potentials	-- Select --	-- Select --	875
Continuous ICU Electroencephalography	-- Select --	-- Select --	
Flash Visual Evoked Potentials	-- Select --	-- Select --	
Intraoperative neuro-monitoring using multi-modality evoked potentials	-- Select --	-- Select --	
Long-term EEG video monitoring using **ONLY surface electrodes**	-- Select --	-- Select --	
Long-term EEG video monitoring using grid recordings **(Subdural monitoring)**	-- Select --	Year 3	
Multiple Sleep Latency Test	-- Select --	-- Select --	
Needle Electromyography	-- Select --	-- Select --	
Neonatal Electroencephalography	-- Select --	-- Select --	
Nerve Conduction Studies	-- Select --	-- Select --	
Pattern Reversal Visual Evoked Potentials	-- Select --	-- Select --	
Polysomnography	Year 3	-- Select --	
Routine Electroencephalography	-- Select --	-- Select --	
Somatosensory Evoked Potentials	-- Select --	-- Select --	
Positive Airway Pressure Therapy	-- Select --	-- Select --	

Next Question

6.10 Block six: Practical skills

PRACTICAL SKILLS

In the following pages you will be presented with **PRACTICAL SKILLS** contributions from **Questionnaire One.**

Each page will ask you to **match SKILLS** to **modalities**

Please **select** each **modality** the **skill applies to** by ticking the box**.**

The aim is for us to determine common foundation skills that link modalities together.

Select N/A if you believe the SKILL does not apply to undergraduate WIL and may or should be EXCLUDED from undergraduate WIL.

NOTE: Each set of skills will be presented THREE times to match with 5-6 different modalities for a total of 16 modalities
***Please select at LEAST ONE answer for all SKILLS**

6.10.1 Quality control

On the next three pages you will be presented with a set of **QUALITY CONTROL** skills to match with 5-6 modalities.

Please **select** each testing **modality** that the listed **skill applies** to.

Select N/A if you believe the SKILL does not apply to undergraduate WIL and may or should be EXCLUDED from undergraduate WIL.

Please select each testing modality that the listed skill applies to.

Select N/A if you believe the SKILL does not apply to undergraduate WIL

	Bedside Electroencephalography	Brainstem Auditory Evoked Potentials	Continuous ICU Electroencephalography	Flash Visual Evoked Potentials	Intraoperative neuro-monitoring using multi-modality evoked potentials	N/A to undergraduate WIL
Annotations *(monitor patient, recording, artifact, drugs, structural defects)*	☐	☐	☐	☐	☐	☐
Aseptic Infection control and safety	☐	☐	☐	☐	☐	☐
Adjust to new research/ standards	☐	☐	☐	☐	☐	☐
Electrical safety	☐	☐	☐	☐	☐	☐
Clean electrode sites: **Impedances**	☐	☐	☐	☐	☐	☐
Apply Protocol/**minimum standards** in all environments and all patients	☐	☐	☐	☐	☐	☐
Troubleshooting and correction: **technical** problems *(Example: equipment position, hardware and software)*	☐	☐	☐	☐	☐	☐
Repeatability/ Reproducibility of serial tests *(Doing the test procedure - hook-up and acquisition- in a standardised way for comparable results between techs and labs and on different patients)*	☐	☐	☐	☐	☐	☐
Artifact recognition/differentiation from activity of interest: Correction; **non-physiologic**	☐	☐	☐	☐	☐	☐
ICU: neat and out of the way set-up of equipment - **work around equipment**	☐	☐	☐	☐	☐	☐

	Bedside Electroencephalography	Brainstem Auditory Evoked Potentials	Continuous ICU Electroencephalography	Flash Visual Evoked Potentials	Intraoperative neuro-monitoring using multi-modality evoked potentials	N/A to undergraduate WIL
Manage/control SLEEP during recording	☐	☐	☐	☐	☐	☐
Replication (averaging) of waveforms during recording of a specific test.	☐	☐	☐	☐	☐	☐
Care of electrode placement site *(invasive and non-invasive)*	☐	☐	☐	☐	☐	☐
Artifact recognition/differentiation from activity of interest: Correction; **physiologic**	☐	☐	☐	☐	☐	☐
Measure 10-20 system electrode placement positions	☐	☐	☐	☐	☐	☐
Sterile Infection control and safety	☐	☐	☐	☐	☐	☐
Troubleshooting and correction: **physiologic** patient related factors *(Example: level of consciousness and focus)*	☐	☐	☐	☐	☐	☐
Recognition and correction of **ICU Specific Artifact**	☐	☐	☐	☐	☐	☐
Accurate distance **measurement**	☐	☐	☐	☐	☐	☐

< **Next** Save & Continue Later

This repeated three times until all skills were evaluated in relation to each modality.

6.10.2 Analysis

On the next three pages you will be presented with a set of **ANALYSIS** skills to match with 5-6 modalities.

Please **select** each testing **modality** that the listed **skill applies** to.

Select N/A if you believe the SKILL does not apply to undergraduate WIL and may or should be EXCLUDED from undergraduate WIL.

Please select each testing modality that the listed skill applies to.

Select N/A if you believe the SKILL does not apply to undergraduate WIL

	Bedside Electroencephalography	Brainstem Auditory Evoked Potentials	Continuous ICU Electroencephalography	Flash Visual Evoked Potentials	Intraoperative neuro-monitoring using multi-modality evoked potentials	N/A to undergraduate WIL
Diagnosis / Classify disease	☐	☐	☐	☐	☐	☐
Pattern recognition: **Identifying Abnormal**	☐	☐	☐	☐	☐	☐
Correlating recording with **video**	☐	☐	☐	☐	☐	☐
Effect of Medication/Drugs	☐	☐	☐	☐	☐	☐
Understand **treatment options**	☐	☐	☐	☐	☐	☐
Apply **Pathophysiology**	☐	☐	☐	☐	☐	☐
Indication of drugs	☐	☐	☐	☐	☐	☐
Recognition and **measurement** of **wave forms/calculations**	☐	☐	☐	☐	☐	☐
Apply **Physiology**	☐	☐	☐	☐	☐	☐
Integrate results from **multiple tests** (NCS/EMG)	☐	☐	☐	☐	☐	☐

	Bedside Electroencephalography	Brainstem Auditory Evoked Potentials	Continuous ICU Electroencephalography	Flash Visual Evoked Potentials	Intraoperative neuro-monitoring using multi-modality evoked potentials	N/A to undergraduate WIL
Apply **Anatomy**	☐	☐	☐	☐	☐	☐
Identifying **sleep features**	☐	☐	☐	☐	☐	☐
Pattern recognition: **Identifying Normal**	☐	☐	☐	☐	☐	☐
Interpret/Compile report: written or verbal : include recording limitations	☐	☐	☐	☐	☐	☐

< **Next** Save & Continue Later

This repeated three times until all skills were evaluated in relation to each modality.

6.10.3 Performance

On the next three pages you will be presented with the a set of **PERFORMANCE** skills to match with 5-6 modalities.

Please **select** each testing modality that the listed **skill applies** to.
Select N/A if you believe the SKILL does not apply to undergraduate WIL and may or should be EXCLUDED from undergraduate WIL.

Please select each testing modality that the listed skill applies to.

Select N/A if you believe the SKILL does not apply to undergraduate WIL

	Bedside Electroencephalography	Brainstem Auditory Evoked Potentials	Continuous ICU Electroencephalography	Flash Visual Evoked Potentials	Intraoperative neuro-monitoring using multi-modality evoked potentials	N/A to undergraduate WIL
Manage sp02 and **intubation**	☐	☐	☐	☐	☐	☐
Patient Preparation: *(safe patient manipulation/ correct positioning/ dignity/ mobility/ comfort)*	☐	☐	☐	☐	☐	☐
Ambulatory recording	☐	☐	☐	☐	☐	☐
Choose correct **stimulation choice**	☐	☐	☐	☐	☐	☐
Equipment machine **knowledge**/ setting manipulation *(Example: Changing filters, programming amplifiers)*	☐	☐	☐	☐	☐	☐
Manage patient events/ **emergencies**	☐	☐	☐	☐	☐	☐
Needle RECORDING **techniques**	☐	☐	☐	☐	☐	☐
Understand/ choose/ modify **montages**	☐	☐	☐	☐	☐	☐
History/ pre-test **evaluation**	☐	☐	☐	☐	☐	☐
Setup video recording	☐	☐	☐	☐	☐	☐

	Bedside Electroencephalography	Brainstem Auditory Evoked Potentials	Continuous ICU Electroencephalography	Flash Visual Evoked Potentials	Intraoperative neuro-monitoring using multi-modality evoked potentials	N/A to undergraduate WIL
Appropriate **Activation** procedures	☐	☐	☐	☐	☐	☐
Asses VA (Visual Acuity)	☐	☐	☐	☐	☐	☐
Work with **Collodion** or similar	☐	☐	☐	☐	☐	☐
Surface Electrode **Placement Stimulating** *(skillful application/hook-up/**accurate** and technically correct)*	☐	☐	☐	☐	☐	☐
Personal Positioning *(comfortable and stable)*	☐	☐	☐	☐	☐	☐
Needle STIMULATION **techniques**	☐	☐	☐	☐	☐	☐
Recognise and **capture Waveforms**	☐	☐	☐	☐	☐	☐
Needle Electrode **Placement Stimulating** *(skillful application/hook-up/ **accurate** and technically correct)*	☐	☐	☐	☐	☐	☐
Manage side effects to testing or treatment	☐	☐	☐	☐	☐	☐
Surface STIMULATION **techniques**	☐	☐	☐	☐	☐	☐

	Bedside Electroencephalography	Brainstem Auditory Evoked Potentials	Continuous ICU Electroencephalography	Flash Visual Evoked Potentials	Intraoperative neuro-monitoring using multi-modality evoked potentials	N/A to undergraduate WIL
Needle Electrode **Placement Recording** *(skillful application/hook-up/ **accurate** and technically correct)*	☐	☐	☐	☐	☐	☐
Surface RECORDING **techniques**	☐	☐	☐	☐	☐	☐
Surface Electrode **Placement Recording** *(skillful application/hook-up/ **accurate** and technically correct)*	☐	☐	☐	☐	☐	☐
Adjust protocol to obtain **relevant information** to question *(Example: placing additional electrodes)*	☐	☐	☐	☐	☐	☐

< **Next** Save & Continue Later

This repeated until all skills were evaluated in relation to each modality.

6.10.3 Communication and management

On the next three pages you will be presented with a set of **COMMUNICATION AND MANAGEMENT** skills to match with 5-6 modalities.

Please **select** each testing modality that the listed **skill applies** to.

Select N/A if you believe the SKILL does not apply to undergraduate WIL and may or should be EXCLUDED from undergraduate WIL.

Select N/A if you believe the SKILL does not apply to undergraduate WIL

	Bedside Electroencephalography	Brainstem Auditory Evoked Potentials	Continuous ICU Electroencephalography	Flash Visual Evoked Potentials	Intraoperative neuro-monitoring using multi-modality evoked potentials	N/A to undergraduate WIL
Calibration and **maintenance** and **testing** of equipment	☐	☐	☐	☐	☐	☐
Obtain cooperation/all ages/ **explain procedure**/	☐	☐	☐	☐	☐	☐
Data collection and management	☐	☐	☐	☐	☐	☐
Theater protocols - work with Theater staff	☐	☐	☐	☐	☐	☐
Maintain records/**documentation** of procedures	☐	☐	☐	☐	☐	☐
Room preparation/plan ahead	☐	☐	☐	☐	☐	☐
Protocol and procedure **development**	☐	☐	☐	☐	☐	☐
Self development- **stay up to date** with developments	☐	☐	☐	☐	☐	☐
ICU protocols - work with ICU staff	☐	☐	☐	☐	☐	☐
Communicate with **hearing disability**	☐	☐	☐	☐	☐	☐

	Bedside Electroencephalography	Brainstem Auditory Evoked Potentials	Continuous ICU Electroencephalography	Flash Visual Evoked Potentials	Intraoperative neuro-monitoring using multi-modality evoked potentials	N/A to undergraduate WIL
Bedside manner: Patient interaction/communication	☐	☐	☐	☐	☐	☐
Communicate staff Drs nurses **colleagues**	☐	☐	☐	☐	☐	☐

< Next Save & Continue Later

This repeated until all skills were evaluated in relation to each modality.

6.10.4 Graduate Attributes

GRADUATE ATTRIBUTES

On the next three pages you will be presented with **GRADUATE ATTRIBUTE** contributions from **Questionnaire One.**

Each page will ask you to **match** an **ATTRIBUTE** to **modalities**.

Please **select** each **modality** the **attribute applies** to by ticking the box.

The aim is for us to determine common foundation attributes that link modalities together.

Select **N/A** for any of the SKILLS you believe do not apply to undergraduate WILL and may or should be **EXCLUDED** in undergraduate WIL.

NOTE: Each set of attributes will be presented **THREE** times to match with **5-6 different modalities** for a total of 16 modalities
*Please select at **LEAST ONE** answer for all **ATTRIBUTE**

On the next three pages you will be presented with a set of **GRADUATE ATTRIBUTES.**

Please **select** each testing modality that the listed skill **applies** to.

Select N/A if you believe the SKILL does not apply to undergraduate WIL and may or should be EXCLUDED from undergraduate WIL.

Please select each testing modality that the listed skill applies to.

Select N/A if you believe the SKILL does not apply to undergraduate WIL

	Bedside Electroencephalography	Brainstem Auditory Evoked Potentials	Continuous ICU Electroencephalography	Flash Visual Evoked Potentials	Intraoperative neuro-monitoring using multi-modality evoked potentials	N/A to undergraduate WIL
Perform under pressure	☐	☐	☐	☐	☐	☐
Enthusiasm	☐	☐	☐	☐	☐	☐
Recognise personal **limits** and **obtain assistance**	☐	☐	☐	☐	☐	☐
Adaptability	☐	☐	☐	☐	☐	☐
Work with different **personalities** (patients and colleagues)	☐	☐	☐	☐	☐	☐
Critical thinking	☐	☐	☐	☐	☐	☐
Teamwork	☐	☐	☐	☐	☐	☐
Professionalism/ work **ethic**	☐	☐	☐	☐	☐	☐
Confidence without Arrogance	☐	☐	☐	☐	☐	☐
Be **focused**, time management/ **organised** method	☐	☐	☐	☐	☐	☐

	Bedside Electroencephalography	Brainstem Auditory Evoked Potentials	Continuous ICU Electroencephalography	Flash Visual Evoked Potentials	Intraoperative neuro-monitoring using multi-modality evoked potentials	N/A to undergraduate WIL
Handle difficult patient	☐	☐	☐	☐	☐	☐
Ability to **concentrate** for **long periods** of time	☐	☐	☐	☐	☐	☐
Listening	☐	☐	☐	☐	☐	☐
Experiencing the test **procedure** to **understand** patient experience	☐	☐	☐	☐	☐	☐
Stay calm	☐	☐	☐	☐	☐	☐
Be receptive	☐	☐	☐	☐	☐	☐
Work with different **age** groups	☐	☐	☐	☐	☐	☐
Steady hands/ Dexterous/ Fine motor control	☐	☐	☐	☐	☐	☐

< Next Save & Continue Later

This repeated until all skills were evaluated in relation to each modality.

6.11 Block seven: Embedded Knowledge Skills

EMBEDDED KNOWLEDGE SKILLS

Next you will be presented with **ESSENTIAL KNOWLEDGE** contributions from **Questionnaire One.**

You will be presented with 11 KNOWLEDGE SKILLS at a time and asked to:

1: Score the **IMPORTANCE** on a Scale from 1 - 9 where **9 represents ESSENTIAL** and **1 represents NOT NECESSARY**.
AND
2: Please indicate in **which year of study** the students must **master** the knowledge skill.
AND
3: Select **N/A** if you believe the SKILL does not apply to undergraduate WIL and may or should be EXCLUDED from undergraduate WIL

Examples are provided in *(Italics)*

The **aim is for us to determine** common **foundation skills,** that link modalities together.

NOTE: Please keep in mind that the WIL period is only 18-20 months.

On the next seven pages you will be presented with the **KNOWLEDGE SKILLS** contributions from **Questionnaire One.**

Please complete the following:

1: Rate the **IMPORTANCE** of each of the **embedded** KNOWLEDGE skills for mastering during **UNDERGRADUATE** Work Ingratiated Learning on a scale of 1 to 9, where **9 is ESSENTIAL** and **1 is NOT NECESSARY**.
AND
2: Indicate **year of learning** (third or fourth year of study) when KNOWLEDGE outcome should be achieved.

OR
3: Select N/A if you believe the SKILL does not apply to undergraduate WIL and may or should be EXCLUDED from undergraduate WIL.

< Next Save & Continue Later

Please evaluate the following KNOWLEDGE SKILLS

Indicate the **importance** of each skill for **graduate** outcomes, and if applicable to undergraduate study, please select the year of learning when the skills should be **mastered.**

Select N/A if you believe the SKILL does not apply to undergraduate WIL

	Importance for integration to Private Practice									Year of learning	N/A to undergraduate WIL
	9 Essential	8	7	6	Moderately Important 5	4	3	2	Not Necessary 1		
General electrophysiologic **recording** principles. *(Acquisition, Averaging, display)*	○	○	○	○	○	○	○	○	○	-- Select --	☐
Know **differences** of **related modalities** *(Example the different Evoked potential tests)*	○	○	○	○	○	○	○	○	○	-- Select --	☐
AASM sleep staging and related event scoring	○	○	○	○	○	○	○	○	○	-- Select --	☐
Importance **GA and CA** *(Know how to calculate)*	○	○	○	○	○	○	○	○	○	-- Select --	☐
Functions and method of working of **ancillary ICU/Theatre equipment** *(BIS/Aneurism Detection/Cerebral Funtion Monitor/Patient Safety Indicators)*	○	○	○	○	○	○	○	○	○	-- Select --	☐
ACNS/IFCN Protocols *(Minimum technical requirements)* for All modalities	○	○	○	○	○	○	○	○	○	-- Select --	☐
Treatment pertaining to modality	○	○	○	○	○	○	○	○	○	-- Select --	☐
Pathophysiology and diseases/diagnosis pertaining to modality *(dysfunction of anatomy being tested, including interrelated organ systems affecting anatomy under investigation)*	○	○	○	○	○	○	○	○	○	-- Select --	☐
Anatomy pertaining to modality *(physical location and connection/relation of structures)*	○	○	○	○	○	○	○	○	○	-- Select --	☐
Physiology pertaining to modality *(generation of activity - function of the anatomy)*	○	○	○	○	○	○	○	○	○	-- Select --	☐

This repeated until all skills were evaluated in relation to each modality.

6.12 Block eight: Conclusion

Please contribute any thoughts or opinions on any **ESSENTIAL** aspect of **UNDERGRADUATE WIL** that was not addressed in the questionnaire:

Next

Save & Continue Later

Please indicate an email address to be used for feedback from this round group responses and for receiving the Round Three questionnaire. The address you provide will ONLY be used to send you analysis feedback and the next round questionnaire.

Next

Save & Continue Later

6.13 End message

Clinical Neurophysiology Education in South Africa Round Two

Thank you for participating as a panellist in the **second round** of my research. You will receive the third round questionnaire based on the panel's responses to provide your further expert opinion at the address you provided.

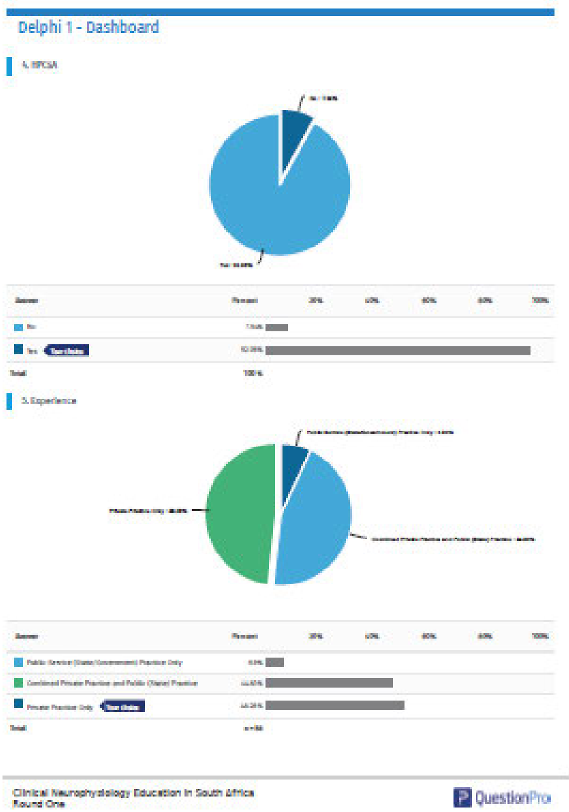
On the next page you will be presented with a report indicating your answers compared to the current overall response results.

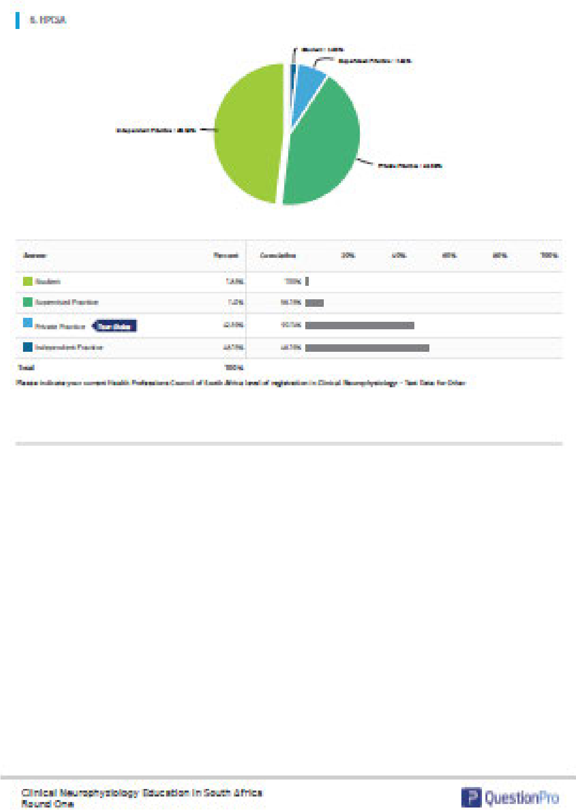
Please **export, save, and retain** this report. You may want to review your answer choices while providing ratings in the Round Three questionnaire.

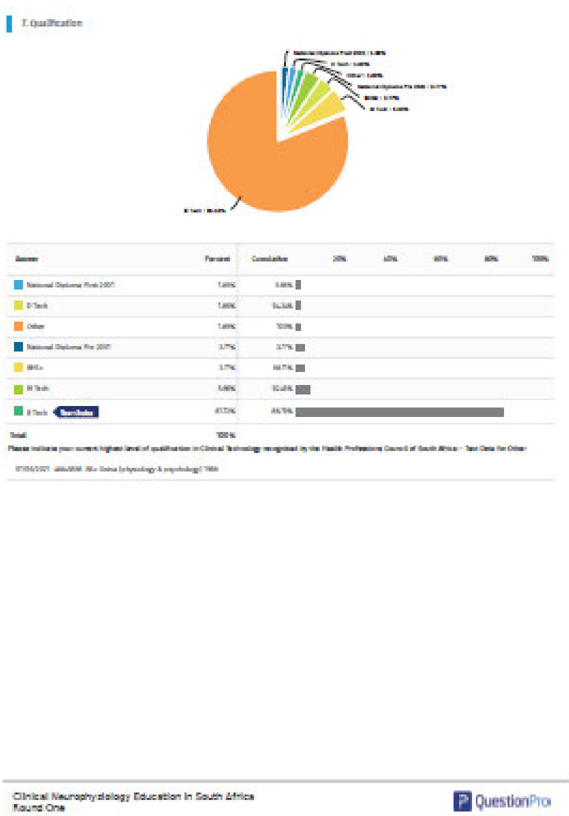
Done

Appendix 7: SpotLight® report

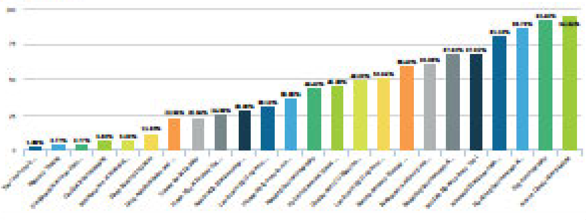
This section displays an example of the SpotLight® report each participant received at the end of each questionnaire.







10. Modalities

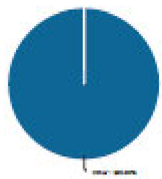


Answer	Percent
Your own choice of additional modality	1.89%
Memory Testing	3.77%
Peripheral Nerve and Muscle Ultrasonography	3.77%
Cortical Brain Mapping	5.66%
Maintenance of Wakefulness Test	5.66%
Deep Brain Stimulation	11.32%
Drug Administration and management of side effects (Text Data)	22.64%
Transcranial Doppler	22.64%
Flash Visual Evoked Potentials	24.53%
Assist with Electromyography	28.3%
Long-term EEG video monitoring using surface AND grid recordings (Subdural monitoring)	30.19%
Intraoperative neuro-monitoring using multi-modality evoked potentials (Text Data)	35.85%
Needle Electromyography (Text Data)	45.28%
Pattern Reversal Visual Evoked Potentials (Text Data)	47.17%
Continuous ICU Electroencephalography	50.94%
Long-term EEG video monitoring using EMU surface electrodes	50.94%
Somatosensory Evoked Potentials (Text Data)	60.38%
Brainstem Auditory Evoked Potentials (Text Data)	62.26%
Bedside Electroencephalography (Text Data)	69.81%
Multiple Sleep Latency Test	69.81%
Neonatal Electroencephalography (Text Data)	81.13%
Routine Electroencephalography	86.79%
Polysomnography (Text Data)	92.45%
Nerve Conduction Studies (Text Data)	94.34%
Total	n=53

Please select up to ten (10) Clinical Neurophysiology Modalities you consider ESSENTIAL to include in the BHS Clinical Technology Neurophysiology Work Integrated Learning program. - Text Data for Your own choice of additional modality

04/06/2021 L693342	
08/06/2021 L693663	
01/06/2021 L642489	
31/05/2021 L687002	
31/05/2021 L687409	
31/05/2021 L689476	
27/05/2021 L689027	Positive Airway Pressure Therapy and Ventilation
27/05/2021 L689762	

12. Additional

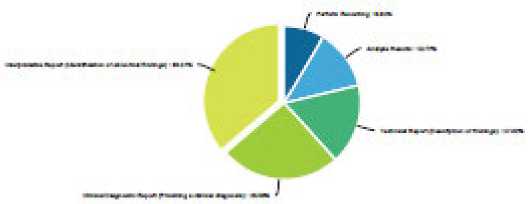


Answer	Percent
Other	100%
Total	100 %

Please indicate the skills ability level you consider essential for our graduates to achieve in your choice of additional modality - Text Data for Other

27/05/2021 L689027 Sufficient exposure to make recommendations on both CPAP and non-invasive positive pressure ventilation (BPAP various modalities)

13. NCS

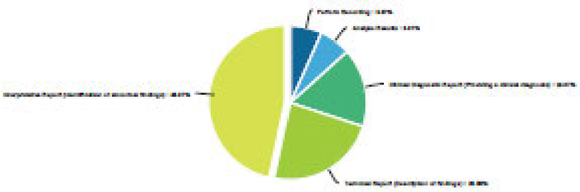


Answer	Percent
Perform Recording	8.00%
Analyse Results	12.77%
Technical Report (Description of findings) (Text Data)	17.00%
Clinical Diagnostic Report (Providing a clinical diagnosis)	26.00%
Interpretative Report (Identification of abnormal findings)	36.17%
Total	100 %

Please indicate the skills ability level you consider essential for our graduates to achieve in "Nerve Conduction Studies" - Text Data for Other

15/04/2021 L730844
07/04/2021 L666069
07/04/2021 L666807
31/05/2021 L687002

14. BAEP



Answer	Percent
Perform Recording	6.67%
Analyse Results	6.67%
Clinical Diagnostic Report (Providing a clinical diagnosis) (Text Data)	16.67%
Technical Report (Description of findings)	23.33%
Interpretative Report (Identification of abnormal findings)	46.67%
Total	100 %

Please indicate the skills ability level you consider essential for our graduates to achieve in "Brainstem Auditory Evoked Potentials" - Text Data for Other

22/06/2021 L772120
11/06/2021 L759634
04/06/2021 L693304
27/05/2021 L690236

Clinical Neurophysiology Education In South Africa
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Appendix 8: Aggregate result of modality learning relationships

Table 0.1 and Table 0.2 shows the selection rates of all modalities as either having a prerequisite or dependency relationship toward all other modalities.

Table 0.1: Total Combined Modality "Prerequisite for" relationship selection rate

Modality	BAEP	Bedside EEG	cICU EEG	EMG	FVEP	IONM	MSLT	NCS	Neonatal EEG	PRVEP	PSG	Routine EEG	SE LTEM	SG LTEM	SSEP
Prerequisite for Bedside EEG	1		0	0	1	0	0	1	1	0	0	32	0	1	0
Prerequisite for BAEP		6	0	0	5	0	0	6	0	1	0	14	0	0	2
Prerequisite for cICU EEG	0	25		0	0	0	2	0	8	0	1	29	10	0	0
Prerequisite for FVEP	3	4	1	0		0	0	4	0	8	1	11	0	0	5
Prerequisite for IONM	25	8	5	15	19		1	17	2	13	1	17	2	2	29
Prerequisite for SE LTEM	0	24	8	0	0	0	0	0	9	0	1	30		1	0
Prerequisite for SG LTEM	2	21	15	1	2	4	0	2	11	2	1	26	25		2
Prerequisite for MSLT	0	6	0	0	0	0		0	0	0	21	24	3	0	0
Prerequisite for EMG	2	0	0		1	0	0	28	0	2	0	1	0	0	4
Prerequisite for Neonatal EEG	0	25	9	0	0	0	0	0		0	1	29	2	0	0
Prerequisite for NCS	0	2	2	0	0	0	0		0	0	0	8	2	0	0
Prerequisite for PRVEP	2	2	1	0	18	0	1	3	0		1	12	0	0	3
Prerequisite for PSG	2	11	2	0	1	0	4	1	1	0		26	8	0	1
Prerequisite for Routine EEG	1	2	1	0	0	0	0	0	1	0	0		0	0	0
Prerequisite for SSEP	10	3	1	1	7	0	0	17	0	5	1	15	1	0	
Total	48	139	45	17	54	4	8	79	33	31	29	274	53	4	46

Table 0.2: Total Combined Modality “Dependent on” relationship selection rate

Modality	BAEP	Bedside EEG	cICU EEG	EMG	FVEP	IONM	MSLT	NCS	Neonatal EEG	PRVEP	PSG	Routine EEG	SE LTEM	SG LTEM	SSEP
Dependent on Bedside EEG	3		27	2	2	2	9	1	22	2	8	0	26	12	1
Dependent on BAEP		0	0	0	3	13	0	0	0	9	0	0	0	0	8
Dependent on cICU EEG	0	0		0	0	1	2	0	2	0	2	0	8	13	0
Dependent on FVEP	1	0	0	0		9	0	0	0	18	0	0	0	0	1
Dependent on IONM	0	0	0	0	0		0	0	0	0	0	0	1	6	0
Dependent on SE LTEM	0	0	14	0	0	1	0	0	2	0	1	0		12	0
Dependent on SG LTEM	0	0	0	1	0	6	0	0	0	0	0	0	0		0
Dependent on MSLT	0	1	0	0	0	0		0	0	0	6	0	0	0	1
Dependent on EMG	0	0	0		0	12	1	0	0	0	0	0	0	1	1
Dependent on Neonatal EEG	0	1	6	0	0	1	0	0		0	0	0	10	5	0
Dependent on NCS	4	0	0	21	2	7	0		0	3	0	0	0	0	18
Dependent on PRVEP	2	0	0	0	9	3	0	0	0		0	0	0	1	0
Dependent on PSG	0	1	2	0	0	0	12	0	1	0		0	1	1	2
Dependent on Routine EEG	7	29	30	1	7	8	16	3	26	8	20		30	16	10
Dependent on SSEP	2	1	0	1	1	23	1	1	0	2	31	0	1	0	
Total	19	33	79	26	24	86	41	5	53	42	68	0	77	67	42

Appendix 9: 1984 Neurophysiology condensed syllabus

NASIONALE DIPLOMA IN KLINIESE TEGNOLOGIE

NATIONAL DIPLOMA IN CLINICAL TECHNOLOGY

NEUROFISIOLOGIE

NEUROPHYSIOLOGY

(Verkorte sillabus / Condensed syllabus)

Vak 9:	Neuroanatomie en Fisiologie 3
Vak 10:	Neuropatofisiologie 3
Vak 11:	Biomediese Apparaat en Metodiek (Neurofisiologie) 3
Vak 12:	Kliniese Praktyk (Neurofisiologie) 3

Subject 9:	Neuro-anatomy and Physiology 3
Subject 10:	Neuropathophysiology 3
Subject 11:	Biomedical Apparatus and Methodology (Neurophysiology) 3
Subject 12:	Clinical Practice (Neurophysiology) 3

September 1984

ENGLISH

NATIONAL DIPLOMA IN CLINICAL TECHNOLOGY

SUBJECT 9 : NEURO-ANATOMY AND PHYSIOLOGY 3

(CONDENSED SYLLABUS)

ANATOMY

1. Skull and spinal column
2. The brain
3. The spinal cord
4. The peripheral nervous system
5. The skeletal muscles

PHYSIOLOGY

1. The Neuron
2. Synapses
3. Reflexes
4. Skeletal muscles
5. Special senses
6. The central nervous system
7. The cerebral circulation
8. Cerebro-spinal fluid
9. Consciousness

General remarks

1. The general standard and contents are similar to that of other para-medical courses as offered by South African universities.
2. Students, and doctors responsible for training, must ascertain themselves of the rules concerning the N.D. in Clinical Technology.
3. For further information the detailed syllabus and lecturer's guide may be consulted.

SEPT. 1984

NATIONAL DIPLOMA IN CLINICAL TECHNOLOGY

SUBJECT 10 : NEUROPATHOPHYSIOLOGY 3

(CONDENSED SYLLABUS)

1. Abnormalities of movement
2. Abnormalities of sensation
3. Abnormalities of consciousness
4. Epilepsy
5. Abnormalities of cortical function
6. General neurology

General remarks

1. Students, and doctors responsible for training, must ascertain themselves of the rules concerning the N.D. in Clinical Technology.
2. For further information the detailed syllabus and lecturer's guide may be consulted.

SEPT. 1984

NATIONAL DIPLOMA IN CLINICAL TECHNOLOGY

SUBJECT 11 : BIOMEDICAL APPARATUS AND METHODOLOGY (NEUROPHYSIOLOGY) 3

(CONDENSED SYLLABUS)

In order to obtain a sound understanding of the facilities at his disposal and to enable him to utilise the equipment to the optimum, the student is expected to have a thorough knowledge, with the emphasis on the functional and practical use of the equipment listed below. Special attention must be given to patient safety aspects as far as equipment as well as the electrical installation of work areas are concerned.

The methodology of specialized application of all equipment must be dealt with at each module. The level will vary depending the importance of the different modules.

1. Electroencephalograph

2. Polygraph

3. Electromyo/neurograph

4. Evoked Potential equipment

5. Computorized systems

General remarks

1. Please note that students must keep a register of amongst other, all the practical work completed during the training period. This training register must be controlled regularly by the clinical technologist responsible for training.

2. Students, and clinical technologists responsible for training, must excertain themselves of all rules in connection with the course, training requirements in general as well as requirements for registration with the Professional Board for Clinical Technology.

3. For further information the detailed syllabus and lecturer's guide may be consulted.

SEPT. 1984

NATIONAL DIPLOMA IN CLINICAL TECHNOLOGY

SUBJECT 12 : CLINICAL PRACTICE (NEUROPHYSIOLOGY) 3

(CONDENSED SYLLABUS)

It is expected form the student to master the following investigations and related procedures.

1. Electroencephalography
2. Polygraphy
3. Electromyography
4. Electroneurography
5. Evoked Potential studies
6. Echoencephalography
7. Patient safety
8. Administration

General remarks

1. Interpretation of results is in general required at a level necessary for the correct and complete execution of the different investigations.

2. Please note that students must keep a register of amongst other, all the practical work completed during the training period. This training register must be controlled regularly by the clinical technologist responsible for training.

3. Students, and clinical technologists responsible for training, must ascertain themselves of all rules in connection with the course, training requirements in general as well as for registration with the Professional Board for Clinical Technology.

4. For further information the detailed syllabus and lecturer's guide may be consulted.

SEPT. 1984

Appendix 10: Editing certificate

DR RICHARD STEELE
BA HDE MTech(Hom)
HOMEOPATH
Registration No. A07309 HM
Practice No. 0807524
Freelance academic editor
Associate member: Professional Editors' Guild, South Africa

154 Magenta Place
Gxarha [Morgan Bay]
5292
Eastern Cape

082-928-6208
rsteele@vodamail.co.za
rsteele201@outlook.com

EDITING CERTIFICATE

Re: **Christelle van der Walt**
Master's dissertation DUT: **A WORK INTEGRATED LEARNING CONTENT FRAMEWORK FOR CLINICAL NEUROPHYSIOLOGY TECHNOLOGY IN SOUTH AFRICAN UNIVERSITIES OF TECHNOLOGY**

I confirm that I have edited this dissertation and the references for clarity, language and layout. I returned the document to the author with track changes so correct implementation of the changes and clarifications requested in the text and references is the responsibility of the author. The intellectual content of the document is the responsibility of the author. I am a freelance editor specialising in proofreading and editing academic documents. My original tertiary degree which I obtained at the University of Cape Town was a B.A. with English as a major and I went on to complete an H.D.E. (P.G.) Sec. with English as my teaching subject. I was a part-time lecturer in the Department of Homoeopathy at the Durban University of Technology for 13 years and supervised many master's degree dissertations during that period.

Dr Richard Steele
16 October, 2023
per email