2019

# Educational Technology Use in Neurodiagnostic Clinical Skills Training

Margaret Ann Marsh-Nation
*Walden University*

# Walden University

College of Education

This is to certify that the doctoral dissertation by

Margaret Ann Marsh-Nation

has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
the review committee have been made.

Review Committee
Dr. Carla Johnson, Committee Chairperson, Education Faculty
Dr. Michael Marrapodi, Committee Member, Education Faculty
Dr. Danielle Hedegard, University Reviewer, Education Faculty

Chief Academic Officer
Eric Riedel, Ph.D.

Walden University
2019

Abstract

Educational Technology Use in Neurodiagnostic Clinical Skills Training

by

Margaret Ann Marsh-Nation

MS, Walden University, 2011

BS, Capella University, 2009

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Educational Technology

Walden University

February 2019

Abstract

The current shortage of clinical sites for neurodiagnostic technology (NDT) students is limiting enrollments and subsequently limiting graduates from NDT schools in the U.S. A lack of knowledge or consensus concerning the use of educational technology in NDT clinical skills training prompted this investigation. The purpose of this study was to explore the use of educational technology in providing NDT clinical skill training. This qualitative Delphi study was guided by experiential learning theory and cognitive constructionist epistemology. Thirty expert panelists were recruited to rate the effectiveness of educational technology methods in addressing neurodiagnostic competencies for electroencephalography. Twenty-four completed round one, twenty-two completed round two and nineteen completed the third and final round. The competencies were derived by combining national competencies or practice analysis from the United States, Australia, Canada and the United Kingdom for neurodiagnostic technologists performing electroencephalography (EEG). Results of the three rounds of the Delphi study were processed using the mean value and interquartile deviation for evaluation of consensus. Consensus among the expert panelists supported the potential effectiveness of educational technology to address neurodiagnostic graduate competencies for technologists performing EEG. In conclusion, the expert panel consensus was NDT clinical skills for performing EEG can be addressed using educational technology, followed by a post-graduate clinical residency. Using educational technology and a post-graduate residency could increase school capacity. An increase in graduate numbers would help sustain the existing schools, better supply the profession, and increase public access to quality neurodiagnostic care.

Educational Technology Use in Neurodiagnostic Clinical Skills Training

by

Margaret Ann Marsh-Nation

MS, Walden University, 2011

BS, Capella University, 2009

Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Philosophy

Educational Technology

Walden University

February 2019

Dedication

I want to thank the panelists in my Delphi study for giving their time and sharing their expertise in neurodiagnostics and educational technology. I could not have done the study without their help. Thank you for your dedication to the completion of my research project.

I dedicate this dissertation research project to my friends around the world who share my love for the field of neurodiagnostics. I learned from selfless professionals who shared their knowledge and generously gave time to my education, namely Bebe McGee Dotter, R. EEG T. and Danny Bartel, M.D. It has been my pleasure and privilege to help dedicated NDT professionals in their educational pursuits. I have especially enjoyed working with NDT professionals in Ethiopia, Gebremichael Werede Tesfay, Hareg Gebremedhin and Tedros Kahsay, who helped me demonstrate that more can be taught at a distance than many in the field thought. I also dedicate this research to my professional colleagues Isiaka Amoo and Murtala Bankole in Nigeria, Elsa Yenshe in South Africa, John Chiwata, Leokadia Tarimo, and Peter Katyali in Tanzania. Their dedication and enthusiasm inspire everyone around them.

I want to especially dedicate my work to the global Neurodiagnostic leaders I have met through the Organization of Societies of Electrophysiological Technology. OSET is a global organization promoting education in neurodiagnostics around the world and it has been an honor to have served as president of this noble organization. I will cherish my OSET friendships always. Special thanks to Daniel Teguo who connected me with neurodiagnosgtic students in Africa through his Global Organization of Health Education. He is tirelessly dedicated to bringing teachers and students together, providing instruments and books to the expanding numbers of NDT professionals around the world. The study of neurodiagnostics and the professionals in the field continue to amaze and challenge me daily.

Acknowledgments

I wish to thank Carla Lane-Johnson Ed.D. and Michael E. Marrapodi Ed.D. for their patience, guidance, and mentoring. I would also like to thank my husband William C. Nation for doing my chores and supporting me in every way, during graduate school and life in general.

Table of Contents

List of Tables

List of Figures

# Chapter 1: Introduction to the Study

The allied healthcare field of neurodiagnostics is facing a challenge: Amid increasing demands for a qualified workforce, fewer clinical sites are available and willing to offer such training. Traditionally, neurodiagnostic technologists (NDTs) have been trained either on-the-job or in a formal training program which included rotation through a clinical neurodiagnostic laboratory according to standards set by the Commission on Accreditation of Allied Health Educational Programs (CAAHEP; 2015) subcommittee, the Committee on Accreditation of Neurodiagnostic Training programs (CoA-NDT; 2018). In recent years, identifying clinical sites willing to host students has become increasingly difficult for many allied healthcare professions including neurodiagnostics, according to ASET – The Neurodiagnostic Society (ASET; 2016) and the National League of Nursing (NLN; 2014; Schott & Cook, 2016). At the same time, the neurodiagnostic profession has grown in complexity with expanded modalities requiring more formal education (Wells & Vaughn, 2013). The limited number of clinical sites available to schools continues to limit enrollments and therefore graduates to supply the increasing need of the workforce (ASET, 2016). Thus, there exists a clinical training problem in the field of neurodiagnostic technology which is increasing over time.

This research explored educational technology alternatives to traditional clinical skill training. Clinical experience may be achieved during a supervised, post-graduate residency prior to credentialing exams. This alternative pathway may provide schools a means to expand enrollments, graduate more professionals, better supply the NDT workforce, and provide more availability of neurodiagnostic care to patients.

## Background

According to data from the CoA-NDT, accredited training programs in the United States graduated a nationwide total of 135 to 271 students per year, between the years 2009 and 2013. Four training programs closed during 2014, and two in 2016 (CoA-NDT, 2018). According to the American Job Center's 2017 data, an estimated 128,000 NDT technologists were working in 2016, and job growth for NDT technologists was projected to be faster than average at 15% or higher during the 10-year period from 2016 to 2026 (American Job Center, 2017). Expanded use of NDTs in the operating room and intensive care units to monitor patients has created growth of the profession, ASET (2014) noted. The projected number of job openings for 2016 to 2026 is a total of 11,000 (American Job Center, 2017; Bureau of Labor and Statistics, 2016). The number of graduates from accredited programs in 2014 was 277, 244 in 2015, 288 in 2016, and 275 in 2017, according to national graduate data (CoA-NDT, 2018). Although not all the schools have reported their graduate data, based on current graduation trends, approximately 855 projected jobs still will be unmet each year (Bureau of Labor and Statistics, 2016; CoA-NDT, 2018). To meet the projected need, the number graduates in the years from 2016 to 2026 will need to grow to 1,100 per year. Every year that graduate numbers fall short of 1,100, the deficit of qualified NDT professionals, therefore, grows.

Wells and Vaughn (2013) conducted a mixed-methods needs assessment by surveying directors of programs accredited by the CAAHEP for polysomnographic, electroneurodiagnostic (also known as neurodiagnostic), and respiratory therapy training programs in the U.S. to determine current and future educational needs in these fields. Wells and Vaughn's results strongly supported the development of more advanced degree programs and affirmed a nationwide shortage of sleep technologists, and an unmet demand for qualified professionals in sleep technology. Sleep technologists have an overlapping scope of practice with the more generalized field of neurodiagnostics according to the American Association of Sleep Technologists and ASET – The Neurodiagnostic Society (AAST, n.d.; ASET, 2011). The Wells and Vaughn study substantiates the need for further study to examine the use of educational technology in clinical skills training to expand the number of graduates in NDT.

The United States had a shortage of nurses estimated to be 500,000 in 2014 by the American Association of Colleges of Nursing (AACN), yet, in 2015, nursing schools denied 69,000 applicants' admission due to lack of nursing faculty, clinical sites, classrooms, clinical preceptors, and budget constraints (Schott & Cook, 2016). Schott and Cook (2016) noted that the AACN is working with the Institutes of Medicine (IOM) to find ways to use technology to overcome the shortage of nurses. AACN and IOM also addressed the need for increased clinical reasoning, integration of rapidly changing medical technology, and interprofessional collaboration and communication skills. Simulations provide learners opportunities to gain competencies and practice skills prior to and during clinical rotations. In support of the studies by Hayden, Smiley, Alexander, Kardong-Edgren, and Jeffries (2014), standards and best practices in simulation by the International Nursing Association for Clinical Simulation and Learning (INACSL; 2016) and the NLN (2014) began supporting that 50% of traditional clinical experiences may be substituted with simulation. Simulation use is approved provided that faculty are formally trained in simulation, and a realistic environment is created with equipment and supplies (NLN). Adequate support for learners with access to faculty, and theory-based debriefing conducted by subject matter experts is also required as noted by NLN, Hayden et al., and INACSL.

The World Health Organization (WHO; 2013) projected that the shortage of healthcare workers will reach 12.9 million worldwide by 2035. Reasons cited by the WHO were an aging healthcare workforce, trained professionals leaving the fields for better pay or less risk of exposure to disease, a decrease in young people entering healthcare fields, and migration of healthcare workers. At the third Global Forum on Human Resources for Health conducted by the WHO, greater political pressure and technical leadership was encouraged to expand training opportunities and increase health-care workforce (WHO, 2013).

If other allied healthcare professions are using educational technology to provide practical clinical skills or clinical reasoning skills to their students, then educational technologies might be used to provide neurodiagnostic students with clinical skills and clinical reasoning skills. The CoA-NDT electroencephalographic (EEG) graduate competencies (CoA-NDT, 2012) and the American Board of Registration of Electroencephalographic and Evoked Potential Technologists practice analysis (ABRET; n.d.) separate neurodiagnostic skills into several categories or domains. The CoA-NDT EEG graduate competencies and the ABRET EEG practice analysis are respected within the field as clear descriptions of the skills needed to perform EEGs (CoA-NDT, 2012). Professional associations for the field in Australia, Canada, and the U.K. have published their own competencies for NDT technologists performing EEG (i.e., Association of Neurophysiological Technologists of Australia [ANTA], 2016; Canadian Association of Electrophysiology Technologists [CAET] 2011; Association of Neurophysiological

Scientists [ANS], 2014). These competencies are similar to the CoA-NDT ones but have some different elements. For this study I have combined the competencies into a single list of competencies needed to perform electroencephalograms (EEGs). The combined list has seven domains and 70 competencies (see Appendix A).

The focus of the literature review is to explore, analyze, and synthesize the practices and applications of educational technologies in addressing similar skills in allied healthcare fields to clinical skills in EEG technology. EEG is one modality of NDT practice (ASET, n.d.). My goal was to identify educational technologies that might be integrated into NDT training and provide structured experiential learning similar to the experiences of a student assigned to a clinical site rotation.

In a Delphi study by Romig, Tucker, Hewitt, and Maillet (2017) examining opportunities and challenges facing allied health deans, clinical education models were rated by the deans as having the largest number of opportunities. Opportunities included the use of collaborative interdisciplinary clinical models in didactic-based teaching, simulation-based learning, and clinical experiences. Findings included linking clinical and didactic education and implementing educational technology to address competencies in programs lacking sufficient clinical sites. This approach optimizes the use of distance learning, computer education and simulation (Romig et al., 2017). Collectively the deans in the Romig et al. study supported exploring the use of educational technology to redesign clinical curricula integrating educational technology such as simulation and standardized patients into clinical education for allied health professionals.

The United States Department of Education conducted a meta-analysis of evidence-based practices in online learning as part of an effort to provide research-based guidance for implementing online learning (U.S. Department of Education, 2010). The goal of the literature review was to evaluate the effectiveness of online learning compared to face-to-face instruction. The Department evaluated the impact of adding online elements in a blended approach and examined best practices and conditions impacting effectiveness of online learning. The criteria for inclusion in the Department's review of literature from 1996-2008 included a contrast of online to face-to-face classroom, measurement of learning outcomes, evidenced based design, and information to calculate effect size (U.S. Department of Education, 2010). Forty-five studies of K-12, medical, military, professional continuing education, and higher education were examined (U.S. Department of Education, 2010). Based on the meta-analysis results, the report authors concluded that student outcomes were modestly better in online learning than in face-to-face classes and that face-to-face classes benefitted from adding online elements for blended (hybrid) learning (U.S. Department of Education, 2010).

Several allied healthcare fields are experiencing difficulty bridging students from theory to practice or from classroom to patient care. Wilkinson, Smallidge, Boyd, and Giblin (2015) explored student perceptions in a qualitative study of various teaching tools and methods to bridge theory to practice in dental hygiene. Wilkinson et al. used retrospective journaling activity with open ended survey questions given to 85 junior and senior dental hygiene students. Wilkinson et al. found among junior students who had not yet experienced clinical practice with live patients that 51% predicted that hands on experiences; 42% predicted critical thinking exercises; and 27% predicted visual aids would be most helpful in preparing them for clinical practice. However, senior students who had experienced clinical practice with live patients identified critical thinking exercises and visual aids as being most beneficial, rating them both at 44% in helping prepare for the transition from classroom to clinical practice. The Wilkinson et al. study concluded that critical thinking exercises were most helpful in preparing students to transition from the classroom to clinical practice.

Educational strategies to assist medical students in the development of clinical reasoning were explored by Cutrer, Sullivan, and Fleming (2013). The theoretical lens used to evaluate strategies was a dual process theory reasoning model addressing specific skills needed for clinical reasoning. Cutrer et al. also used a conscious competence model utilizing a developmental road map leading to clinical reasoning. Strategies evaluated in the Cutrer et al. critical literature review were scaffolding, teaching from presentation to diagnosis, direct observation of data-gathering, and processing skills. Cutrer et al. evaluated a framework to report, interpret, manage, educate (RIME), and present problem-based or short case-based scenarios. Cutrer et al. explored verbalization of the learner’s thought process using a method to summarize, narrow, analyze, probe, plan, and select (SNAPPS). Improvement of metacognition (thinking about thinking), taking a diagnostic timeout (fresh look, review, differential diagnosis), awareness and identification of cognitive biases, and reflection (both reflection in action and reflection on action) were included in the Cutrer et al. study. The identification of tools and methods for clinical-reasoning training informs allied healthcare instructors of ways to customize training in clinical, critical-thinking skills according to Cutrer et al. These methods could be applied to neurodiagnostic clinical skills.

Third year students at the Illinois College of Optometry (ICO) were given image rich clinical cases to evaluate in a hybrid course to expand clinical problem-solving, data analysis, and processing skills needed for clinical practice in a study by Wyles, McLeod, and Goodfellow, (2013). In the Wyles et al. case study, a team of faculty developed problem-based learning scenarios using real patient histories and supporting data that students could access online, evaluate in a non-threatening environment, and answer online questions. The students then met in quarterly primary care conferences where the cases they studied online were presented and discussed. Feedback from students indicated perceived improvements in success on standardized exams so ICO plans to expand the program to begin in the first year and continue through the third year. Wyles et al. cited online delivery of clinical cases saves instructional time for interactive discussion without taking class time to present lengthy case studies.

The Argus Commission of the American Association of Colleges of Pharmacy (AACP) reported changes in education and healthcare (Raehl et al., 2013). The Argus report cited the increased demand for higher education, the need for higher productivity and lower cost higher education institutions to expand access. The Argus Commission report also noted the shifting of student populations to nontraditional environments, more use of technology in instruction, and new models of education which would expand availability (Raehl et al., 2013). The increasing use of educational technology in healthcare education opens new opportunities for providing clinical skills, clinical reasoning, and problem-solving training to larger numbers of students to prepare them for clinical practice (Raehl et al., 2013).

Educational technology strategies can be used to promote clinical reasoning skills (Shellenbarger & Robb, 2015). Shellenbarger & Robb and Robb (2015) reported the use of electronic concept maps, electronic case histories, and digital storytelling in clinical reasoning training for nurses. Concept maps can be hand written or created with software. These maps help students link and visualize complex concepts, and promote metacognition, reflection, insight, and transferring knowledge into clinical situations according to Shellenbarger & Robb and Robb. Technology rich electronic case histories linked to course objectives, outcomes and enhanced with audio or video recordings, hyperlinks, graphics, and images can create a sequential case development scenario allowing exercise of clinical judgement by the student. Case histories also help students in the organization of information, establishment of priorities, and creation of an appropriate plan of action. Digital storytelling can be used to promote communication, collaboration, and reflection, which aid development of clinical reasoning capabilities (Shellenbarger & Robb, 2015).

A literature review evaluating the impact of technology-enhanced learning environments as part of a blended approach to clinical education of allied health, medical and nursing students was conducted by Rowe, Frantz, and Bozalek (2012). Seven articles were included, evaluating the use of blended learning, computer aided instruction, integrated learning, hybrid learning, and multi-method learning. All but one of the Rowe et al. reviewed articles showed some measure of improvement in student reflective thinking skills, clinical skills, documentation, patient management, and clinical self-efficient clinical reasoning. Two of the studies suggested a blended approach using clinical scenarios could bridge the gap between theory and practice as reported by Rowe et al.

Some specific healthcare professions have developed tools to structure clinical reasoning such as the Systematic Clinical Reasoning in Physical Therapy (SCRIPT) tool evaluated in a case study by Baker et al. (2017). Developed in 1994 at the Army-Baylor University Doctoral Fellowship in Orthopedic Manual Physical Therapy facility, the SCRIPT tool may be used to provide insight to post-professional residency or fellowship training programs. The tool is a systematic structured method of gathering data about potentially involved structures and making judgments. The method brought the sometimes-unconscious cognitive process of clinical reasoning to a conscious level for the student (self-reflection) and mentor to examine the mentee's thinking process according to Baker et al. The Baker et al. study brought the process to a conscious level and facilitated meta-cognition or thinking about thinking. Such a tool could be developed as a framework for clinical reasoning development in other allied healthcare professions such as NDT.

## Problem Statement

The current shortage of clinical sites through which NDT training programs can rotate their students has resulted in some NDT school closings in the United States and a national total graduate number of less than 300 per year (CoA-NDT, 2018). As reported by ASET (Bonner, 2016), the shortage of clinical sites has limited the number of students and graduates from existing training programs. ASET conducted a national campaign to recruit additional clinical sites for the 23 accredited and nine unaccredited schools in the

United States. However, the campaign resulted in only 21 additional clinical sites in the national ASET clinical site registry (Bonner, 2016).

Possible alternatives to clinical skills training in clinical sites include creative use of educational technology as described by Warren, Lee, and Najmi (2014). Warren et al. described these methods as encompassing a learner-focused, social constructivist design that stimulates natural instincts to learn by situating learning in a realistic task, narrative, or problem, creating understanding through experience. The Warren et al. methods involved using visual representations, three-dimensional learning environments, synchronous and asynchronous communication tools, and web-based instructional materials. Exploring the use of experiential learning through simulation or problem, case, scenario, or story-based learning may remove the limitations imposed by the shortage of clinical training sites according to Warren et al. While several other allied healthcare professions have begun to use educational technology to address clinical skill training, I did not discover any studies exploring such alternatives in neurodiagnostic technology training in my literature searches. I enlisted the assistance of a Walden University librarian but was not able to locate any studies about the use of educational technology in neurodiagnostic technology, either.

## Purpose of the Study

The purpose of this qualitative Delphi study was to explore innovative educational technology alternatives for NDT students to obtain clinical skills. By combining the knowledge of NDT professionals, NDT educators, and educational technology experts, I sought to achieve consensus about the potential use of educational technology in NDT clinical skills training. If educational technology can provide clinical skills training, it may allow NDT training programs to increase enrollments, producing more graduates to fill the increasing demand for qualified NDT professionals.

## Research Questions

RQ 1: What are the informed judgments of an expert panel of neurodiagnostic professionals, neurodiagnostic educators, educational technology experts, and educational technology educators about the use of educational technology in clinical skills training for neurodiagnostic technology students?

RQ 2: Does consensus exist, or can it be achieved through the Delphi process, among experts in educational technology and neurodiagnostic technology about the use of educational technology in clinical skills training for neurodiagnostic technology students?

## Conceptual Framework

The conceptual framework of this study included the exploration of educational technologies to create an experiential learning environment (Aubrey & Riley, 2016; Donmez & Cagiltay, 2016; Kolb, 1984; Quay, 2003). While clinical experience provides an environment for clinical skill development, clinical reasoning skills can result from experiential learning designed to engage the learner in technology-based experiences that mimic clinical cases (de Oliveria et al., 2015). I used cognitive constructivist epistemology (Schrader, 2015) to guide my research. Constructivism refers to ways in which people make meaning and construct knowledge (Schrader, 2015). Building active learning through engaged experiences such as simulation, case-based, scenario-based, story-based, or problem-based learning could become tools for clinical reasoning skills instruction (Frederickson et al., 2013).

The conceptual framework also included experiential learning theory. Experiential learning theory is an instructional design model that is used to create a student-centered environment for learners to engage in a transformational experience (Aubrey & Riley, 2016; Kolb, 1984). Such experiences put knowledge to work in solving real-world problems or situations, either in a heuristic, team, or guided model (Donmez & Cagiltay, 2016). According to Kolb (1984), experiential learning begins at any point along a cycle of exposure to a concrete experience, observation and reflections, abstract conceptualization, and active experimentation. These experiences of doing, observing, reflecting, thinking, and trial become learning opportunities and can begin at any point in the cycle (Kolb, 1984).

Experiential learning opportunities can occur in a clinical environment, classroom, workshop, or online and make use of case, problem, scenario, story-based learning, or simulation (Donmez & Cagiltay, 2016). Experiential learning uses engagement, critical thinking opportunities, and reflection to deepen contextual understanding and application of theoretical concepts (Donmez & Cagiltay, 2016; Kolb, 1984). The use of educational technology can create experiential learning for students who experience situations through case studies, stories or simulations (Donmez & Cagiltay, 2016).

## Nature of the Study

This study employed the qualitative Delphi technique. A Delphi study is an iterative research tool for experts to make informed projections about unknown future trends or as a tool for consensus building (Dalkey, 1969). Panelists communicated anonymously in the evaluation of statements and new statement ideas using a Delphi instrument which contained statements to be rated by the expert panel (Keeney, Hasson & McKenna, 2011). The Delphi instrument provided the panelists with statements and asked them to rate the importance or effectiveness of each statement. The panelists were encouraged to make new statements which were added to the list for the next round. The panelists were provided feedback with results of each round of the Delphi instrument including median rating of effectiveness of the statements and a list of all additional statements. After reviewing the feedback, the panelists were asked to rate the statements again. After three to four rounds of the Delphi instrument, the results were evaluated for consensus and reported (Adler & Ziglio, 1996; Dalkey, 1969; Keeney et al., 2011).

**Types and Sources of Data**

Data sources included the following:

1. The first round of statements utilized a combined list of the neurodiagnostic graduate competencies and ABRET practice analysis (ABRET, n.d.); the Committee on Accreditation of Neurodiagnostic Training Programs (CoA-NDT, 2012); Association of Neurophysiological Technology of Australia (ANTA, 2016); the U.K. Association of Neurophysiological Scientists (ANS, 2014); Canadian Association of Electrodiagnostic Technologists (CAET, 2011) paired with educational technology practices found in the literature.
2. Ratings, comments, and suggestions from expert panelists during the three rounds were the data examined for consensus and effectiveness rating. An optional fourth round could have been administered if there was no consensus in three rounds of the Delphi study (Hsu & Sanford, 2012).

**Sample Size**

The sample size of 30 is the mean sample size for qualitative research (Boddy, 2016). The number of Delphi expert panelists are generally between 15 and 20 (Hsu & Sanford, 2012) and rarely exceed 30 (Sekayi & Kennedy, 2017) but the expansion to 30 was needed to include 15 individuals from NDT and 15 from educational technology. A target sample size of 30 provides additional members of the panel beyond the customary 15 to 20 (Hsu & Sanford, 2012), as some attrition of panelists was expected. Though 30 panelists agreed to participate, 24 actually completed round one, 22 completed round two and 19 completed the third and final round.

## Definitions

*American Board of Registration of Electroencephalographic and Evoked Potential Technologists* (ABRET): ABRET is the credentialing organization for neurodiagnostic technologists performing electroencephalography, evoked potentials, intraoperative neuromonitoring, and magnetoencephalography (ABRET, n.d.).

*ASET – The Neurodiagnostic Society*: The largest national society for neurodiagnostics in the United States. Formerly the American Society of Electroneurodiagnostic Technologists, the society nostalgically retained the acronym ASET in the formal society name and members still refer to the society as ASET (ASET, n.d.)

*Case-based learning (CBL)*: A pedagogy that uses authentic medical case examples to train medical and allied health professionals by engaging the student in the details of the case (Fortun, Morales, & Tempest, 2017). Cases are designed from initial contact to diagnosis and treatment or from the presentation of the patient for testing to the conclusion of testing (Fortun et al., 2017). This method increases performance and motivation of students. It has been used in medicine for many years to promote critical thinking and clinical reasoning but is now being incorporated earlier into the curriculum earlier in healthcare professions to promote clinical reasoning skills (Fortun et al., 2017).

*Clinical reasoning*: High-level cognitive and reflective strategies involving metacognition or "thinking about thinking" that is often subconscious and essential in the development of clinical experts (Baker et al., 2017).

*Clinical reasoning*: As broadly defined by Furze et al. (2015), the thought processes and judgments associated with making decisions, plans, and actions by a healthcare provider in clinical practice.

*Clinical skills*: Skills used in performing care for patients including procedural steps, practical underlying science knowledge, skills in communication, observations, practical application of testing or treatment, task analysis, problem-solving, and clinical reasoning (Michels, Evans, & Blok, 2012).

*Critical thinking*: A cognitive and behavioral process involving analytical knowledge, open-minded truth-seeking, interpretation, and reflective thinking that can be applied to the assessment and resolution of specific problems (Paul, 2014).

*Educational technologies*: The study and ethical practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources (Association for Educational Communications and Technology, 2012).

*Neurodiagnostic technology*: An umbrella term for recording different types of electrophysiological activity from the brain, or central and peripheral nervous systems.

These procedures include electroencephalography, evoked potentials, polysomnography, nerve conduction studies, long-term monitoring for epilepsy (LTM), intensive care monitoring, intraoperative neuromonitoring, magnetoencephalography, or autonomic reflex testing (ASET – The Neurodiagnostic Society, 2016).

*Organization of Societies of Electrophysiological Technology (OSET)*: An international society for neurodiagnostic professional organizations and individuals in countries without professional societies (OSET, 2017).

*Problem-based learning (PBL)*: A form of learning that has its origins in medical training and is intended to build critical or clinical judgment through the student-centered practice of realistic problem-solving experiences (Wyles et al., 2013)

*Scenario-based learning*: A form of learning that places the learner into a specific set of circumstances calling for appropriate decisions to be made in a student-centered experiential learning environment. Scenarios can be experienced through reading, engagement, or interaction in an online environment or discussion in a classroom (Barbera, Garcia, & Fuetes-Alpiste, 2017; Persson, Dalholm, Wallergard, & Johansson, 2014; Weston, 2015)

*Story-based learning* (SBL): A pedagogical method using rich, engaging stories of patients and families to involve students in an emotional, social, ethical, economic, and cultural experience that goes beyond the clinical case presentation by having participants examine situations from different perspectives. It is student-centered learning in which learners are exposed to different perspectives in situations through reading, discussing, or adopting different perspectives within a detailed story. SBL is engaging and can add situational awareness to instructional design (Lavoie, Cossette, & Pepin, 2016; Shaw, Lind, & Ewashen, 2017).

## Assumptions

I assumed that effective use of educational technology for clinical skills training in other allied healthcare professions may be equally successful when used in neurodiagnostic technology. The study assumed that the expert panelists would achieve consensus in the Delphi process. The study also assumed that the grouping of experts with equal representation of educational technology and neurodiagnostic technology achieved a balanced view of the separate fields and insights into potential application of educational technology to neurodiagnostic technology clinical skills training. The study also assumed there would be some attrition of panelists completing the study so a target of 30 panelists was set, which resulted in an actual participating number of 24 in round one, 22 in round two and 19 in the third and final round.

## Scope and Delimitations

The study focused on the competencies for electroencephalographic (EEG) technologists. EEG is one aspect of the neurodiagnostic technology profession. Most schools of NDT begin with EEG technology and later expand into other modalities of NDT. The study was limited to pairing educational technology methods with 70 combined EEG competencies which appear in the Delphi instrument as 138 statements (ABRET, n.d.; ANS, 2014; ANTA, 2016; CAET, 2011; CoA-NDT, 2012). While the competencies of other English-speaking countries were combined into the Delphi statements, the study was limited to panelists from within the United States. The study addresses the NDT profession but may have some transferability to other allied healthcare professions in the same way studies from nursing, physical therapy, pharmacy, and dental school studies have informed this study.

## Limitations

It was beyond the scope of this study to address all aspects and modalities of the neurodiagnostic profession. Future studies may address other modalities of NDT. The competencies in EEG are extensive making the Delphi study time consuming for the expert panelists. The researcher brought an optimistic view of the use of educational technology to the study and journaled during the process to monitor potential bias. Since several schools of NDT make use of online courses, the results of the study would at the least isolate those competencies for which the use of educational technology was in doubt. The expert panelists' ratings of methods of educational technology effectiveness in addressing the competencies, are potentially helpful to NDT educators, regardless of overall outcomes. Though responses were not attributed to individual panelists, it cannot be completely ruled out that panelists may have felt peer-group pressure to comply with the majority of the panelists. The study was focused on NDT and specifically EEG, but may have some transferability to other allied healthcare professions. Attrition was expected as in most Delphi studies (Keeney et al., 2011). The number of Delphi expert panelists are generally between 15 and 20 (Hsu & Sanford, 2012) and rarely exceed 30 (Sekayi & Kennedy, 2017). By targeting 30 participants, when the number of participants in round one decreased to 24, in round two to 22 and round three to 19, the final result was in keeping with the 15 to 20 participant range for a Delphi expert panel (Hsu & Sanford, 2012).

## Significance

Since demand is high for trained NDT professionals and the limited number of clinical sites often caps the numbers of graduates, this study examined alternative pathways to clinical skills training (ASET, 2016). More graduates of NDT schools would result in the positive social change of more neurodiagnostic care for patients. More students and graduates would also insure a future for the NDT educational institutions because more students would result in greater financial success and long-term stability of NDT schools and training programs (ASET, 2016).

## Summary

In Chapter 1, I defined the problem caused by a shortage of clinical learning sites and explained the approach to exploring alternatives. The conceptual framework and nature of the study have been explained including assumptions, scope, boundaries for inclusion and limitations. The significance of the study was potentially to expand enrollments in all NDT schools and explore alternative pathways to NDT clinical skills. Chapter 2 provides a review of the literature exploring possible educational technology and methods to address the critical-thinking, clinical-reasoning, and problem-solving skills associated with neurodiagnostic clinical skills. Chapter 3 presents a plan for the Delphi study. Chapter 4 summarizes the results of the study. Chapter 5 presents future areas of study associated with the use of educational technology in NDT and other allied healthcare fields.

# Chapter 2: Literature Review

## Introduction

The problem of clinical site shortages for NDT students has led to low graduate numbers from existing schools of NDT (ASET, 2016; CoA-NDT, 2018). Possible alternatives to clinical skills training include creative use of educational technology as described by Warren et al. (2014). Warren et al. described these methods as encompassing learner-focused, social constructivist design that stimulates natural instincts to learn, by situating learning in a realistic task, narrative, or problem, creating understanding through experience. The purpose of this qualitative Delphi study was to explore innovative educational technology alternatives for NDT students to obtain clinical skills. This chapter includes reviews of literature addressing clinical skills, critical-thinking, and clinical-reasoning with the use of educational technology in various allied healthcare fields similar to NDT. I begin the chapter by describing my literature search strategy and the study's conceptual framework.

## Literature Search Strategy

The review of literature includes clinical skills, critical thinking, or clinical reasoning skills instruction in allied healthcare education using problem-, case-, story-, or scenario-based learning and simulations in virtual, clinical, or classroom settings. I conducted searches using Education Source, ERIC, ProQuest Nursing and Allied Health Source, Science Direct, Academic Search Complete, and ProQuest dissertation databases. Searches of ASET, the Neurodiagnostic Society's online journal library, were conducted but no educational technology in NDT articles were found. In addition, I elicited the assistance of a Walden University librarian to search for articles about educational technology use in clinical skills training for neurodiagnostic technology but was unable to find any studies on the topic. As I was not able to locate articles about the use of educational technology in neurodiagnostic training specifically, the focus of this literature review is on exploring educational technology use in nursing and other allied healthcare professions to address various types of clinical skills.

Nurses, medical students, radiology technologists, respiratory care technologists, physical therapists, pharmacists, and other allied healthcare students train in clinical settings or address clinical reasoning in their curricula. As reported by Galloway (2009), other allied healthcare professions are experiencing a shortage of clinical training placement sites. These healthcare professions have moved toward using educational technology methods for patient safety or expanding graduate numbers according to Galloway. Allied healthcare educators have recognized that simulation, or learning based on cases, scenarios, stories, or problems, can be designed to be inclusive of a full spectrum of clinical case types or situations as stated by Galloway. Even those clinical cases rarely seen in a clinical rotation or on rounds are important to a professional knowledge-base and clinical reasoning skills (Lunney, 2010; Raurell-Torredá et al., 2014). These rare cases can be incorporated via case-based learning (McLean et al., 2014).

The key words used in the searches were, as follows: *neurodiagnostic technology education*; *simulation in healthcare education*; *problem-based*, *case-based*, *story-based*, or *scenario-based learning in healthcare education*; *critical thinking*; *clinical reasoning*; *theory to practice gap*; *healthcare education*; and *clinical skills education.* The review begins with definitions of clinical skills, clinical reasoning, and critical thinking skills and an examination of how these skills are addressed with different types educational technology. Then, I examine the literature concerning the use of problem-, case-, story-, or scenario-based learning and simulation in clinical skills training and assessment in allied healthcare fields.

There is some overlap between these types of educational technology. Simulations are often developed around a case-study, story, scenario, or problem (Romero-Hall, 2016). Some other useful educational strategies discovered in the literature are considered potentially useful in neurodiagnostic clinical training (Lavoie et al., 2016; Zori, 2016). I explored innovative learning strategies that aid deep learning and used in conjunction with educational technology. Situational awareness (Lavoie et al., 2016), reflective journaling after a simulation or clinical experience (Zori, 2016), and a database of terms (Rodger et al., 2014) used to provide feedback to students are strategies that might be applied to educational technology methods to enhance clinical skills training. Each strategy is discussed in the following literature review.

I decided which topics to include in the literature review based on the application of educational technology in clinical skills for nursing, medical students, or allied healthcare training and demonstrated validity. Educational technology techniques, used in other fields, may apply to NDT clinical skills and have been included in the literature review. Techniques, standards, guidelines, databases or other unique applications of technology with potential use in NDT clinical skills training were also included. Studies concerning clinical skills or clinical reasoning most directly applied to clinical skills in NDT. Studies addressing skills particular to NDT, were few in number when searching the literature. Selecting the articles from searches for simulation in clinical skills; clinical reasoning; or problem-, case-, scenario-, or story-based learning in clinical skills or clinical reasoning was more challenging. There is an abundance of literature on these topics. Studies selected addressed aspects of clinical skills similar to NDT clinical skills, including professional attributes such as communication, collaboration, teamwork, clinical confidence, leadership, assessments, or best practices.

My literature search did not reveal research on neurodiagnostic clinical skill training using educational technology as an alternative to assignment to clinical site rotations during didactic training. To address this gap in the literature, the goal of this study was to explore educational technology solutions addressing the graduate competencies needed for neurodiagnostic technologists performing EEG studies. If the majority of the clinical skills in the list of competencies can be addressed with educational technology, it might be possible for NDT students to be prepared for clinical practice in a supervised residency after graduation but before credentialing. This pathway could expand enrollments resulting in larger numbers of graduates from the existing schools thereby addressing the shortage of NDT professionals.

## Conceptual Framework

### Experiential Learning Theory

The conceptual framework for this Delphi Study was experiential learning theory guided by a constructivist epistemology. Experiential learning is defined as a cycle of learning involving action, reflection, experience, and abstraction (Dewey, 1933; Kalkbrenner & Horton-Parker, 2016; Kolb, 1984) which involves the cultivation of interest and effort into active learning. It involves personal engagement, evaluation by the learner, meaning-making of significance, and incorporation into the cognitive process that guides behavior, attitudes, and personality (Dernova, 2015).

Experiential learning begins with a situation that is intellectualized by the student who then brainstorms strategies and uses reasoning to examine consequences of potential strategies, later implementing and testing success of the strategies (Kalkbrenner & Horton-Parker, 2016). The process can be done independently or collaboratively. Experiential learning involves realistic experiences used to bridge the gap between theoretical learning and practice by providing realistic cases, scenarios, stories or problems similar to those encountered in the work environment (Dewey, 1933; Kalkbrenner & Horton-Parker, 2016; Kolb, 1984).

The advantage of experiential learning in healthcare provider training over direct clinical experience is safety for patients, decreased stress for learners, and inclusion of many experiences not commonly experienced in a clinical environment. Rare experiences can require important skills to be in place. A curriculum designed with experiential learning modules can address even rare clinical situations (Kalkbrenner & Horton-Parker, 2016).

**Cognitive Constructivist Epistemology**

Piagetian-based constructivist epistemology is based on the philosophy that knowledge is constructed through interaction between the learner's current understandings and meaning derived from engagement with investigative experiences (Schrader, 2015). Originally, Piaget described cognitive constructivism arising through the learner's interaction with the social and physical world through a process of assimilation and accommodation (Schrader, 2015). Piaget's world has been extended through educational technology and various forms of media creating engaging experiences through interaction with technology and provide social learning opportunities via media and technology (Schrader, 2015). These experiences evolve the learner's knowledge and perspective similar to real-world engagement (Schrader, 2015). The experience of lecture presentation, demonstration, interaction, communication, discussion and sense of learning community are common elements of online learning (Schrader, 2015). When simulation, problem-, scenario-, case-, or story-based learning are added, critical thinking or reasoning skills may develop in a virtual space (Cutrer et al., 2013; NLN, 2014; Shellenbarger & Robb, 2015).

**Cognitive task analysis**. Cognitive task analysis (CTA) is a step by step analysis of procedural skills including those steps automatically or unconsciously done during the performance of a competency (Tjiam et al., 2012). It examines the critical thinking skills and reactions performed by experts that may be missed in lesson plans and learning objectives (Tjiam et al., 2012). The Task Analysis Guide in Science [TAGS] (Tekkumru-Kisa, Stein, & Schunn, 2015) is a structured framework for pairing categories of science instruction with examples of actual science tasks performed by scientists in the field. Cognitive task analysis is the first step to building courses that develop cognitive skills addressing clinical reasoning and critical thinking needed to perform in a clinical environment (Tjiam et al., 2012).

Cognitive demand or cognitive load is the level of critical thinking required for the task (Tekkumru-Kisa et al., 2015). Cognitive demand levels are structured in the TAGS framework from low level memorization tasks, to scripted tasks, to tasks involving guidance and understanding and the highest level of doing actual science (Tekkumru-

Kisa et al., 2015). Each of these tasks can be addressed in content and in practice or both (Tekkumru-Kisa et al., 2015). A similar framework of integrating elements of practice with content or pairing tasks with categories of learning could be applied to NDT.

## Literature Review Related to Key Variables and/or Concepts

### Use of Educational Technology in Clinical Skills Training

Educational technology is being used increasingly in healthcare education (Gaze, 2015). Traditionally, healthcare education began in a classroom where didactic instruction of concepts and theory were established. The classroom was followed by pragmatic application of concepts and theory during the clinical experience where critical thinking becomes essential (Gaze, 2015; INACSL, 2016; Schott & Cook, 2016; WHO, 2013).

Educational technology has been used to begin the development of practical clinical skills and clinical reasoning during didactic training and to bridge the gap between didactic learning and clinical practice (Paul, 2014). Educational technology has the advantage of providing a safe environment for development of clinical skills and clinical reasoning (Raurell-Torredá et al., 2014). It can be structured to begin with basic clinical cases then lead to cases with greater complexity, to include essential learning objectives that build clinical practice and reasoning skills (McLean, Brazil, & Johnson, 2014).

Clinical skills have been described by Michels et al., (2012) as physical assessments of patients, history taking, practical procedural knowledge, communication, management skills and critical reasoning skills. Educational technologies associated with clinical skill training include but are not limited to simulation, problem, case, story or scenario-based learning (Cutrer et al., 2013; Rivkin, 2016; Shellenbarger & Robb, 2015). If the groundwork of clinical reasoning skills is laid using simulation and problem, case, story or scenario-based learning, then training could culminate in paid residencies (Furze et al., 2015). During residencies, newly graduated technologists could gain experience under supervision by credentialed professionals before taking their credentialing exams. This could expand the number of enrollments and graduates from NDT training programs and begin to alleviate the current critical shortage of graduates from NDT training programs (ASET, 2014; American Job Center, 2017; Bureau of Labor and Statistics, 2016).

**Clinical Reasoning and Critical Thinking Skills Instruction**

The terms clinical decision making, critical thinking and clinical reasoning are often used interchangeably. Recognizing this, Furze et al. (2015) broadly defined clinical reasoning as the thought processes and judgments associated with making decisions, plans and actions by a healthcare provider in clinical practice. Clinical skills have been defined by Michels et al., (2012) as procedural steps, practical underlying science knowledge, and clinical reasoning skills with supportive skills including communication, observation, history taking, task analysis, problem-solving and critical thinking. Shellenbarger & Robb and Robb (2015) defined clinical reasoning as collecting cues, information processing and synthesis, and understanding the patient’s problem. Shellenbarger & Robb and Robb described the next phase of clinical reasoning as planning interventions while taking into consideration alternative actions, evaluating outcomes and reflecting upon the process of clinical reasoning. Shellenbarger & Robb and Robb noted that skills requiring critical analysis, synthesis and reflection are noted to be an integral part of the identity of health professionals and are not acquired in the same educational environment as procedural training.

Critical thinking is an essential element of clinical skill performance for allied healthcare professionals. Two sentinel studies have defined the cognitive processes involved in critical thinking. Lunney (2010) applied the seven cognitive skills and ten habits of mind from Scheffer and Rubenfeld's Delphi study (2000) to nursing critical thinking. The seven cognitive skills include analyzing, applying standards, discriminating, information seeking, logical reasoning, predicting and transforming knowledge (Lunney, 2010; Scheffer & Rubenfeld, 2000). The ten habits of mind include self-confidence, contextual perspective, creativity, flexibility, inquisitiveness, intellectual integrity, intention, keeping an open mind, perseverance and reflecting on what is learned (Scheffer & Rubenfeld, 2000).

Critical thinking was defined by Zori (2016) as the foundation of clinical reasoning for nurses including a set of skills and behaviors driving decisions and actions. In her descriptive study, she analyzed journal entries, interviews and written narratives from 71 nursing students during the first seven weeks of intensive care and emergency room fellowships. Zori identified several critical thinking dispositions and asked the nursing student to reflect on these. The dispositions cited by Zori included inquisitiveness, inclination toward systematic approaches, truth seeking beyond preconceived notions, application of analytical or logical reasoning and evidence to solve problems, open mindedness, self-confidence, and maturity. Purposeful use of reflective journaling was shown in the Zori study to be a useful strategy that may be applied to other allied healthcare professional's training as they transition from students to professionals.

**Summary of Clinical Skills and Application to Neurodiagnostics**

Clinical skills for NDT, like other allied healthcare procedures include a range of skills as outlined in EEG and NDT competencies (ABRET, n.d.; ANS, 2014; ANTA, 2016; CAET, 2011; CoA-NDT, 2012). In accordance with competencies set by ABRET (n.d.), CoA-NDT (2012), ANTA (2016), CAET (2011) and ANS (2014), these skills include a professional attitude; interest in continued learning; self-confidence, knowledge of the science of EEG; sequencing appropriate steps in procedures; critical analysis of patient status; and discriminatory analysis of waveform responses. Clinical reasoning also involves critical thinking and problem-solving skills (Lunney, 2010; Zori, 2016). Patient rapport, communication with patients and other healthcare professionals, recognition of emergency situations, and identification of neurological signs and symptoms are also essential skills as stated in the competencies by ABRET, ANS, ANTA, CAET and the CoA-NDT. Troubleshooting the EEG instrument is important for technologists working alone. Similar to other healthcare professions, clinical skills in NDT are not simply a checklist of duties (ABRET, n.d.). Clinical NDT skills involve commitment to integrity and professional standards and an appreciation of the responsibility of being entrusted with patient care (ABRET, n.d.; ANS, 2014; ANTA, 2016; CAET, 2011; CoA-NDT, 2012).

Simulations and problem-based learning (PBL) scenarios have an advantage in providing a wide variety of clinical situations, abnormalities, problems, and clinical reasoning opportunities that may not always occur in every set of clinical site rotations for students (Warren et al., 2014; Wyles et al., 2013). Simulations, cases and scenarios can be designed to provide exposure to cases rarely seen in clinical laboratories. These simulations and PBL would provide virtual experience for students to remember during a post-graduate residency at the end of their didactic training (Pappas, 2015). With clinical reasoning types of simulation experience and problem-solving skills in place, the technologist should have skills in place from the start of their residency, internship or apprenticeship (Lunney, 2010; Zori, 2016). With these skills in place the resident should be professionally marketable (Lunney, 2010; Zori, 2016).

**Assessment of Critical Thinking**

The assessment of nursing critical thinking skills was addressed in a Delphi study by Paul (2014) who concluded critical-thinking is essential for nurses. The path to critical-thinking is varied and individualized according to Paul. Paul concluded that multiple assessment tools are needed for nurse educators to evaluate critical-thinking. Benner, Stuphen, Leonard, and Day (2010), concluded that clinical judgment is more than a list of tasks associated with a situation; it is the integration of theory and practice requiring active learning strategies.

Longitudinal development of clinical reasoning across a curriculum in Doctor of Physical Therapy students at Creighton University was explored in a qualitative study by Furze et al. (2015). The Furze et al. study used the Clinical Reasoning Reflection Questionnaire (CRRQ) and narrative comments from the Clinical Performance Instrument (CPI) with 98 student participants. Results showed progression in clinical reasoning and clarified the process as slowly evolving throughout the curriculum following Dreyfus' five stage model of adult skill acquisition, novice, advanced beginner, competence, proficiency, and expertise (Dreyfus, 2004). During the Dreyfus stages, students evolve from a context-free, detached analytic process to an experienced, situational, intuitive process (Dreyfus, 2004).

In the Furze et al. study, the curriculum began with foundational sciences, essential clinical skills coursework with basic case studies, later included clinical integrative complex cases and contextual science. Clinical experiences were introduced during breaks between semesters and the curriculum ended with full-time clinical experience. The significance of the Furze et al. study is the realization that clinical reasoning begins with the basic science behind the practice and builds slowly as the student evolves from a novice focusing on self with compartmentalized thinking and limited responsibilities. Furze et al. concludes clinical reasoning evolves as the student begins to focus less internally, less rigidly, more contextually, more outwardly focused, with expanding awareness of the patient's needs and acceptance of responsibility. Exposure to increasingly complex case-based learning and gradual exposure to clinical experience help to build clinical reasoning throughout the curriculum according to the Furze et al. study.

Otago Polytechnic School of Midwifery in New Zealand studied the use of Video Assessment of Midwifery Practice Skills (VAMPS) for first year bachelor's degree students in a study by McIntosh, Patterson, and Miller (2018). Students in the McIntosh et al. study filmed themselves in a group role play exercise then used the video to perform a self-evaluation using a rubric. After the self-evaluation, instructors in the McIntosh et al. study provided grading of the video assessment. The McIntosh et al.

study results indicate VAMPS is a useful way for students to demonstrate their competence in practice skills.

Self-awareness of aseptic technique skills was evaluated using video self-reflection activity at Drake University by Dy-Boarman et al. (2017). One hundred six of the second-year pharmacy students participated in the Dy-Boarman et al. study. Students were asked to evaluate their aseptic technique immediately after completion then again after reflection and viewing pf the video. Faculty also evaluated their aseptic technique according to standards. The goal of the Dy-Boarman et al. study was to see if video improved self-awareness of aseptic technique. No significant improvement in self-awareness was reported after viewing the video in the Dy-Boarman et al. study but the university intends to expand the use of video self-awareness activities. One factor not considered in the study is the impact on self-assessment accuracy when the students are aware their practice is being evaluated by video. The knowledge of the video may have kept self-evaluations more accurate.

Cognitive task analysis (CTA) based educational videos have been used in online delivery to train plastic surgeons at Sunnybrook Health Sciences Centre in Toronto, Ontario, Canada (Yeung et al., 2017). The use of CTA brings a broader body of knowledge into the educational demonstration videos and address decision-making processes (Yeung et al., 2017). Bringing this to students before they enter the operating room helps develop clinical reasoning before contact with patients (Yeung et al., 2017). CTA involving consultation with experts adds a level of detailed deep learning to instructional video demonstrations that enhance outcomes and minimize risk (Yeung et al., 2017).

**Sequencing Practice and Theory Training**

Traditional sequencing of NDT clinical reasoning has been in a clinical environment at various stages of training. Constructivist and socio-cultural approaches to sequencing practice and theory to achieve optimal conditions for learning was the focus of the Falk, Falk, and Jakobsson's (2016) mixed methods study of 123 Swedish undergraduate nursing students. In the Falk et al. study, Group A received clinical practice prior to theoretical studies and Group B received theoretical studies prior to clinical practice. Participants in the Falk et al. study, were evaluated qualitatively via reflective journal entries and quantitatively using a self-reporting instrument. The self-reporting instrument used in the Falk et al. study was the Directed Learning Readiness Scale for Nursing Education (SDLRSNE) which evaluates self-management, desire for learning and self-control. Results showed that the sequencing of practice and theory was not statistically significant quantitatively, though qualitatively the students in both groups of the Falk et al. study, believed that theory should precede practice. Falk et al. suggests that early introduction of clinical cases through educational technology may prepare novice students for clinical thinking by exposure to the goal of clinical training. Similarly, NDT students may benefit from exposure to clinical cases early in training.

The Pharmacists' Patient Care Process (PPCP) includes collecting patient data, analyzing the data, development of patient treatment plan, implementation of the plan, monitoring and reassessing the plan (Joint Commission of Pharmacy Practitioners, 2014). Rivkin (2016) developed a design for early implementation of PPCP using patient case learning in first year training for doctors of pharmacy (PharmD). Rivkin used a group of 85 students, divided into 11 groups, who met biweekly and used iPads to access library resources. Rivkin used instant polling and online deconstructive exercises with patient case presentations. Rivkin's study required analysis of a simulated medication history scenario, assessment of drug-related problems, development of a plan for monitoring care and using subjective, objective, assessment and plan (SOAP) notes. Case presentations and small group discussions were followed by full class discussion and brief didactic segments. Students in Rivkin's study were able to self-evaluate their skills, develop confidence and begin a systematic approach to the development of clinical problem-solving skills, using the PPCP, combined with didactic and experiential elements of the curriculum. The Rivkin study concluded that structuring experiential case-based learning builds clinical reasoning skills which could be applied to all allied healthcare fields.

McMaster University's Bachelor of Science in Nursing program in Canada revised their curriculum in 2008 creating what they called a *Kaleidoscope Curriculum,* as reported by Landeen et al. (2016). The curriculum focused on clinical reasoning and judgement, an adaptation of problem-based learning, integration of pathophysiology and evidence-informed decision-making in the Landeen et al. study. The curriculum also provided an introduction of service learning in the first two years of the four-year degree, an integration of inter-professional education and introduction of clinical simulation. The Landeen et al. study illustrated an innovative multi-modality approach to applying educational technology to clinical skills training.

Physical therapy (PT) students were followed in a longitudinal study of diagnostic reasoning by Gilliland (2017). The qualitative Gilliland study used a simulated patient case scenario and the think-aloud method of assessment. Gilliland examined the sequencing of student training with the first year focusing on anatomical structures, and the second year on biomechanical factors. Gilliland found this sequencing led the students to begin their clinical practice focused on movement and biomechanical aspects of the patient's diagnosis without consideration of the impact on the patient's life or degree of disability. Diagnostic reasoning, Gilliland concluded should be a focus in early PT student courses to promote growth of diagnostic reasoning and perception of the patient as a whole.

**Learning Based on a Problem, Case Study, Story or Scenario**

Problem-, case-, story-, or scenario-based learning uses patient cases or problems encountered in a clinical setting. These cases are used to develop a story-line or scenario that can be described in text, acted by simulated patients or students roll-playing, depicted in video online or in a classroom (Clark, 2013). According to Clark, the goal of these educational methods is to take the learner through the analysis of the situation, form a plan to address the situation, and make appropriate choices of action. In problem-based learning a specific issue is addressed in a short description (Wyles et al., 2013). In case-based learning a patient history and physical might be combined with certain test results to create a picture of the patient's health (Gee, Thompson, Strickland, & Miller, 2017). The case is followed by questions about appropriate courses of action from the healthcare professional (Gee et al., 2017). Story-based learning provides the learner with more information about the patient's family, culture, and socio-economic status (Shaw et al., 2017). Story-based learning helps the healthcare professional gain understanding and compassion from experiencing the perspective of the patient, parents, and family (Lavoie et al., 2016). Scenario-based learning places the learner in a particular situation involving several issues and clinical decisions for the healthcare professional (Persson et al., 2014).

**Problem-based learning**. Problem-based learning (PBL) was described by Wyles et al. as a potential educational technology tool to bridge the gap between didactic and clinical education of optometry school students, in a primary care conference hybrid approach. As reported by Wyles et al. the goals of the PBL included development of an attitude of lifelong learning, enhancement of knowledge base, expansion of clinical thinking using visualization of data, problem-solving, procedural management and preparation for credentialing exams. The use of a learning management system (LMS) was integrated into the classroom in the Wyles et al. study to provide a low stress practice environment for problem solving and application of clinical reasoning addressed in didactic curriculum. Students were given clinical cases followed by questions and class discussion in the Wyles et al. study. Through a wide variety of cases, students developed clinical skills and identified weaknesses in their clinical knowledge reported Wyles et al. Class discussion improved overall performance 28 percent compared to PBL without discussion in the Wyles et al. study. Based on student impressions in the Wyes et al. study the PBL helped them pass credentialing exams.

Qualitative perceptions of 25 instructors teaching fourth year clinical courses and practicums was the focus of research by Landeen et al. (2016). After a comprehensive renewal of the curriculum, including one problem-based learning course per semester and a more student-centered approach was integrated into all courses in the Landeen et al. study. The faculty shared stories of their experiences with students in the new curriculum showing evidence of deep learning reported Landeen et al. In the Landeen et al. study themes among the stories were coded as pulling together knowledge; skill and reasoning; building confidence; seeing the patient as a whole person along with family; finding their nursing voices as team members; questioning usual practice and advocating for clients and self. Faculty in the Landeen et al. study noticed positive changes in clinical learning outcomes from the integration of problem-based learning and a more student-centered approach.

Clinical problem-solving ability was evaluated in 190 new graduate nurses (94 in CBL group and 96 in control group) in Korea using case-based learning (CBL) by Yoo and Park (2014). The Yoo and Park study was a quasi-experimental design using pre-test, intervention and posttest. Results showed statistically significant difference in objective problem-solving ability scores after participating in video presentation of cases, individual analysis of the case, and group discussion of the case. A control group with graduate nurses was given traditional lectures focusing on the same illnesses as the case-based learning presentations in the Yoo and Park study. The results of the Yoo and Park study support CBL as a more successful method of teaching problem-analysis, decision making and problem-solving compared to didactic teaching.

In a 4-year retrospective case study involving 1056 students, which was conducted at St. George's University of London, Ellaway, Poulton, and Jivram (2015) tracked the development of decision-problem-based learning (D-PBL). The Ellaway et al. (2015) study used a hybrid activity for small groups using virtual patients and focusing on patient management decisions and their consequences. Debate around alternative patient management options was encouraged during the study. The Ellaway et al. study used branching scenarios with decisions leading different students to different outcomes. The D-PBL process in the Ellaway et al. study was conducted in a classroom with smart-board tabulation and mapping of student choices at various decision points. During the process, the instructor has access to a map to the best outcome but when the exercise was completed, the students were given the outcome map during the reflection and debriefing that followed the exercise in the Ellaway et al. study. The Ellaway et al. D-PBL method adds debate to the discussion process allowing learners to research their options, defend their choices, and adapt to the consequences, possibly correcting poor choices and avoiding poor outcomes. The method used by Ellaway et al. requires more input from learners and less from facilitators, resulting in a more engaging debate and more learning objectives met.

In an effort to increase patient safety, reduce patient litigation and alleviate the problem of clinical site shortages problem-based learning was examined in 87 third-year, pre-registration, general nursing students in an Irish nursing school by Nevin, Neill, and Mulkerrins (2014). Nursing instructors developed and piloted the simulated learning package based on the development cycle of Mohide and Drummond-Young (2001) who established an eight-step process of developing key objectives. The Mohide and Drummond-Young eight steps included prioritizing problems and common health issues first. Clinical problems should be drawn from actual patient cases stated Mohide and Drummond-Young. Instructors should provide supplementary resources for students, seek participant feedback and revise as needed in accordance with Mohide and Drummond-Young. A pilot presentation of the problem package should be conducted and revised as needed then the problem package should be integrated into the curriculum (Mohide & Drummond-Young, 2001). Participants in the Nevin et al. study were surveyed and found it realistic and useful in building confidence, knowledge and clinical skills. Participants in the Nevin et al. study had difficulties with support prior to the simulation and expressed a need for a more structured debriefing process. Debriefing was found to be the phase of the simulation in which theory and practice come together through critical reflection on performance and built clinical thinking skills in the Nevin et al. study.

McLean et al. (2014) transitioned problem-based learning into virtual learning simulations. Bond University in Gold Coast, Australia developed a mobile application called Bond Virtual Hospital that creates realistic context for exposing learners to complex medical cases and prepare them to transition from preclinical training to clinical training. The university performed a pilot study in 2013 using the same cases used in prior classroom paper-based problem-based learning (PBL) changing only the delivery method to a patient-oriented, learner-driven approach using the virtual hospital mobile application. The university's formerly *paper-based patients* became *virtual-patient*s with simulated patients role-playing case scenarios in videos within the application. Learners in the McLean et al. study reportedly found this superior in interactivity and more representative of real-world experiences.

The application used in McLean et al. released relevant information beginning with the patient's name, a photo, video or voice recording, history, physical exam, previous physician notes, vital signs, test results such as blood tests or ECG sequentially (twice a week). This information was given to individuals then later to teams of six to eight medical students in the McLean et al. study. Students in the McLean et al. study discovered gaps in their own knowledge prompting self-directed research and study to fill the gaps.

Later in the McLean et al study, teams were formed to collaborate and brainstorm the patient's diagnosis or manage the treatment as a medical team would perform. In the McLean et al. (2014) study and a later study by Doshi (2016) each virtual patient case presentation was followed by instructor led debriefing to reinforce learning. In both studies, the Doshi study (2016) and the McLean et al. study (2014) these types of problem-based virtual learning exercises provide a learning safety net of important topics in a structured fashion rather than placement in a clinical site which provides random opportunities for exposure to clinical experiences. The cases a student experiences in a clinical rotation may not include some important but rarely seen cases types (Doshi, 2016; McLean et al., 2014).

A comparison of problem-based learning (PBL) to online patient cases by Al-Dahir, Bryant, Kennedy, and Robinson (2014). One hundred and nineteen pharmacy doctorate students were randomly assigned to two groups in the Al-Dahir et al. quantitative study. The demographics of the two groups were similar in the Al-Dahir et al. study. One group participated in a virtual, online patient-simulation, using branching scenarios, while the other group participated in problem-based learning group also with faculty led discussion of branched scenarios in the Al-Dahir et al. study. The assessment results of pre-tests, posttests and student perceived satisfaction were tracked for both groups in the Al-Dahir et al. study. Students' mastery of objectives was similar but the PBL group but the PBL group was slightly more effective with an 8.3% improvement from pre-test to post-text scores. The researchers in the Al-Dahir et al. study admit the students were more familiar with the faculty led PBL approach which may account for the difference. The Al-Dahir et al. study supports the use of both problem-based learning branched scenarios and online virtual patient branched scenarios (simulations) for achieving learning objectives.

**Case-based learning**. The use of case-based learning in dietetics and nutrition education was evaluated in the phenomenological study triangulated with Bloom's Taxonomy, by Harman et al. (2015). In the Harman et al. study, students were interviewed and surveyed after experiencing carefully designed case-based learning modules associated with cooperative communication among learners. Participants in the Harman et al. study reported better problem-solving skills and increase in recall of the cases because of the supportive details. If case-based learning can improve problem-solving skills, this supports the use of case-based learning in clinical skills for NDT learners.

Gee et al., (2017) used mixed methods to study the development process for a tool in simulated case scenarios that would provide a more generic map for other developers to use. In the Gee et al. study, online simulated case scenarios were developed for graduate occupational therapy student's clinical reasoning development and assessment prior to clinical fieldwork. Presented with a difficult case history and video of a patient, the students in the Gee et al. study were given a list of interventions and asked to both prioritize and rationalize or justify their choices.

Evaluation of the specific tool used were mixed with a Cronbach's alpha of .61 (low to moderate) but surveys of students in the Gee et al. study reported their positive impressions of the experience. The students in the Gee et al. study provided documentation of the process for developing the online simulated case and may be educational for other allied health education programs. The development steps listed in the Gee et al. study included identifying and developing the case scenario; listing potential solutions; organizing the possible solutions; ranking them as to appropriateness; pilot the case scenario to a group of professionals; then revise as needed.

A quantitative study of 27 second year Doctor of Physical Therapy students taking a course on examination, evaluation and treatment, was conducted by Trommelen, Karpinski, and Chauvin (2017). The Trommelen et al. study compared scores using the Diagnostic Thinking Inventory (DTI) and the Self-Assessment of Clinical Reasoning and Reflection (SACRR). The three assessments (two pretests and one posttest) were given before the course. An assessment was given before the introduction of five case-based learning (CBL) scenarios in the Trommelen et al. study. This was followed in the Trommelen et al. study by the intervention of external reflective articulation (three written assignments graded on comprehensiveness, agreement, depth and justification) and the posttest was given at the conclusion of the course. Results in the Trommelen et al. study showed a statistically significant increase in SACRR ($p$ = .001) and DTI ($p$ = .01) and student self-reporting of increased clinical reasoning after reflection was implemented. These results of Trommelen et al. support the addition of explicit teaching of external articulated reflection in combination with case-based learning to support development of clinical reasoning.

During the academic year of 2010 - 2011, nursing students at the University of Ljubljana and University of Primorska, in Slovenia participated in a study comparing online and traditional classroom delivery of an ethical competency course (Trobec & Starcic, 2015). The course used in the Trobec and Starcic (2015) study was titled *Philosophy and Professional Ethics in Nursing.* The course goals in the Trobec and

Starcic study were development of values, beliefs and ethical orientation that impact clinical judgment, decision making on a cognitive level, emotional-motivational level and behavioral level. During the Trobec and Starcic study, online learning was conducted in a collaborative environment where students reach common goals solving tasks or problems using active learning, role playing and a multiple case-study format. The Trobec and Starcic study's 436 students were randomly divided into a control group C and experimental groups A and B. The lecture portion of the course in the Trobec and Starcic study was delivered the same way in all groups but the tutorial portion of the course was delivered using the same ethical situation scenarios. Active learning methods such as collaborative tasks, discussions, reflective assignment and role playing were conducted in a classroom setting for group C and in an online format in groups A and B in the Trobec and Starcic study. Pre and posttests were performed using Structure for Observed Learning Outcomes – SOLO taxonomy, and Non-parametric test, a Mann-Whitney test to measure significance of difference between the two groups in the Trobec and Starcic study. The results of the Trobec and Starcic study indicated no significant difference between the scores or ethics exams or a questionnaire. All students in the Trobec and Starcic study showed improvements from pre-tests and posttests and the impressions of students in both groups was positive for both learning and the experience of the delivery method.

Case-based learning and simulation were examined in a nonrandomized trial study of undergraduate nursing students in Spain by Raurell-Torredá et al. (2014). The Raurell-Torredá et al. study followed the trends set in 1999 known as the Bologna Process led by European Ministers of Education working to construct a European Higher

Education Area (EHEA). EHEA was adapting to the changing societal needs, scientific advances in knowledge and specifically the use of human patient simulators (HPS). The advantage of HPS is the ability to introduce students to scenarios that are seldom seen in clinical practice but are highly important reported Raurell-Torredá et al. Simulations can be structured to include all aspects of important clinical cases and experiences according to Raurell-Torredá et al. and Lunney. Scenarios in the Raurell-Torredá et al. study were developed from real patient cases by a professor with many years of experience, following the instructions of Lunney.

CBL is being incorporated earlier in medical student training according to Fortun et al., (2017). The Fortun et al. (2017) study was a mixed-methods study at Herbert Wertheim College of Medicine in the years 2014-2015, involving 130 students, showed both improved scores and student satisfaction when CBL is incorporated into the curriculum. The Fortun et al. study concluded that early introduction of CBL with increased level of difficulty helps students acquire the ability synthesize information promoting clinical reasoning and adds clinical relevance to foundational courses.

**Scenario-based learning.** A prototype for computer-based scenarios designed for medical technology were developed and evaluated in a mixed methods study by Persson et al. (2014) in Sweden. The design of the prototype used by Persson et al. was a participatory design process including three researchers and three practitioners. The practitioners included two senior nurses and one assistant nurse. The development process in the Persson et al. study began with observation and discussion of possible problems to address, issues in the work environment and progressed to low-fidelity prototypes to test design concepts and later high-fidelity prototype development. The scenario problems for the Persson et al. study were based on clinical reality. The Persson et al. study goal was to create an engaging tool to provide training to build confidence among staff in the use of respiratory medical instruments. The Persson et al. study workflow depicted in the scenario began with an event, associated measurable parameters, clinical observations and ended with an appropriate action followed by feedback for the participant on the quality of their response to the event. The feedback in the Persson et al. study also contained items for discussion and links to more detailed information along with a cartoon depiction of the patient state and level of distress (calm, discomfort, reduced oxygen, critically reduced oxygen). The Persson et al. study demonstrated the use of visual interactive learning tools in healthcare education including medical technology in the clinical context. It was noted by the researchers in the Persson et al. study that there was some resistance to this type of learning by older nurses with more than 10 years of experience compared to younger nurses. Overall the scenarios in the Persson et al. study were effective, enjoyed by participants who felt the process was motivating, provided a platform for shared experience, collaborative learning, and helped bridge the gap between theory and practice. A prototype for NDT instrumentation could be developed to create an engaging interaction for NDT students with simulated instruments.

Barbera et al. (2017) conducted a case study in Spain that included participatory co-design development methods [teachers and students] in the development of a learning-scenario based on learner-centered inquiry. Breaking from the tradition of teachers authoring instruction, the Barbera et al. study made use of student a collaborative process in workshops structured in five phases to prepare, explore, envision, operationalize, exact and refine the learning scenario. There were three versions of the scenario developed by the team in the Barbera et al. study, the final version incorporating ideas from all members with teachers and students working together along with researchers acting as moderators in this action-research project. Participatory co-design of learning scenarios is an effective development process providing equal involvement of researchers, students and teachers in the Barbera et al. study. Including students in the design of scenarios may ground NDT instructors and help them remember a time when they did not know all they know and understand now.

In the work by King (1993) teachers were encouraged to move from the position of a *sage* or learned instructor on the stage to a *guide* on the student's side. King reported the focus should not be a teacher-centered learning environment where the teacher is actively giving information and students were passive receivers or containers of learning. The teacher as a guide, according to King, creates student-centered learning where engaged students become producers of their own learning.

However, Weston (2015) suggests the guide on the side can be elevated to an *impresario* with a scenario. Weston outlines three forms of scenarios including role playing, problems as scenarios and microcosms and analogues. Through the mastery of positional roles students can engage in games or reenactments of the processes in which critical decisions, future challenges or historical events take place as stated by Weston. Through learning about the event, challenge or process Weston observed the students learn to speak, write, analyze, solve problems, lead and work as a team. These skills prepare them for future challenges according to Weston.

Scenarios have been used by NASA (2012) and Odyssey of the Mind (2017) as well as Weston to provide problems for students to solve with limited resources and time. Weston suggests that teachers go beyond guiding students and that they immerse themselves in the problem being addressed and live co-actively in the problem, inviting students to join in the challenge. Microcosms and analogues in keeping with Weston's view are scaled down versions of real situations in which students participate in the actual work that may be done by professionals in real work situations. If the topic of study is not easily scaled down to a workable microcosm, then a similar situation with similar decision processes and problem-solving skills can be constructed reported Weston. Weston concluded learning scenarios should require an application of rigorous logic. The level of engagement and reality-based scenarios described could be integrated into realistic scenarios for neurodiagnostic training.

Gavgani, Hazrati, and Ghojazadeh (2015) performed systematic review and meta-analysis of randomized controlled trials for digital case scenarios compared to paper case-scenarios. The analysis of Gavgani et al. included five studies and 222 students. The Gavgani et al. study concluded that digital and paper case-scenarios were equally effective in promoting critical thinking and clinical reasoning. Seventy-three percent of students were more satisfied with digital scenarios reported Gavgani et al. Ninety percent rated digital scenarios more time-saving than paper-based scenarios in the Gavgani et al. study.

Czeropski (2015) studied changing of behavior and intrinsic motivation in a case study involving a mid-sized company's order entry process. The process in the Czeropski study was structured in phases starting with initial training; followed by on-the-job training; scenario-based training; more on-the-job training; a final online test that incorporates the scenario; branched scenarios and simulations. The Czeropski design used Ruth Clark's scenario-based learning model (Clark, 2013). The design also incorporated Iverson and Colky's (2004) collaborative learning themes similar to the Clark (2013) model with the addition of peer communication.  Keller's (2008) ARC model of arousing curiosity, showing relevance and give learning control to the student was used. Keller's (2010) model of identifying goals, establishing objectives and describing changes needed in motivation and attitude were also used. Clark's elements include designing tasks in the scenarios that mimic realistic decisions made and demonstrate knowledge or skills gained. Clark suggests designing a *trigger event* to open the scenario, providing information needed, guidance and instruction, feedback or consequences of choices followed by reflection.

**Story-based learning and situational awareness training**. Stories have long been known to be an engaging, powerful and emotional element of learning design effectively connecting the learner to the content (Paliadelis et al., 2015). In the Paliadelis et al. (2015) study, Australian nursing educators used story-based learning to enhance clinical learning due to the shortage of clinical learning sites. The program used in the Paliadelis et al. study has been offered twice with 284 learners participating. Seventy-three percent of participants in the Paliadelis et al. study found the story-based learning enjoyable; 80% found they gained insights; and 74% thought the process improved their practice.

Story-based learning is an innovative tool to create experiential learning that opens the student to not only the role of the healthcare professional but can place them in the role of the patient or other healthcare professionals according to Shaw et al. (2017). Shaw et al. found story-based learning exposes learners to the experience of differing perspectives. Story-based learning differs from scenario, problem and case-based learning in the addition of perspectives as demonstrated by Paliadelis et al. and Shaw et al. The method reported by Paliadelis et al. can also enlighten staff about the role and responsibility of supervisors contributing to better understanding of the overall healthcare system.

Story-based learning (SBL) is a pedagogical method using rich engaging health-related stories of patients and families as demonstrated by Shaw et al. Story-based learning is used to engage students in an emotional, social, ethical, economic, and cultural experience that goes beyond the clinical case presentation reported Shaw et al. The Shaw et al. study used the Harlequin persona (Doll, Wear, & Whitaker, 2006), of a clown or jester wearing a mask, who represented a fluid androgynous duality in story-based learning. Curriculum as Harlequin (Doll et al., 2006) was used by Shaw et al. in an instructional method using stories that challenge stereotypes by examining the status-quo from various perspectives.

In story-based learning the student is challenged to wear the mask of a different perspective and for a time live the experiences of another person, patient, co-worker. *Harlequin-inspired SBL* as used by Shaw et al. promotes student recognition of their own learning needs, builds on existing knowledge and embraces the complexities such as social, emotional, cultural and socioeconomic issues impacting patients. The complexity of the first-person story told from differing perspectives can help students see different sides of the same situation according to Shaw et al. Story-based as demonstrated by Shaw et al. provides learning that elicits emotion, is complex, and encourages examination of multiple problems, challenges and issues beyond the basic medical condition. Stories were designed by Shaw et al. to cause student growth, force them to step out of their comfort zone, avoid stereotyping, challenge the status quo, their beliefs and expectations. SBL is recognized as potentially bridging the gap between theory and the realities of clinical practice in pediatric nursing as observed by Shaw et al. Story-based learning could be used to help NDT students recognize, have compassion for and identify with the needs of their patients.

Situational awareness is an important factor in simulation training effectiveness as reported by Lavoie et al. (2016). Lavoie et al. developed an instrument used in conjunction with the Situation Awareness Global Assessment Technique (SAGAT), developed by military aviation educators, to evaluate 234 bachelor-level nursing students. The Lavoie et al. study used the instrument in a critical care course during a patient deterioration simulation.

The goal of the Lavoie et al. research was to create and validate the tool that uses SAGAT-type queries indicating perception, comprehension and projection of information as a measure of clinical judgment in a patient deterioration scenario. Evaluation of situation awareness along with assessment of outcomes can add a level of depth to understanding simulation training effectiveness were the focus of the Lavoie et al. study. The depth of understanding gained by story-based learning and situational awareness could help NDT students in the development of insights into the lives of their patients and coworkers.

**Simulation Training in Virtual, Classroom, and Clinical Environments**

**Types of simulations.** Simulation can be defined as an imitation of reality, a state of affairs or process for the practice of problem-solving skills and judgment development (Arthur, Levett-Jones, & Kable, 2013). Virtual worlds, web-based multidisciplinary, multimodal and inter-professional simulations are being used worldwide in medicine (Rosen, 2008). Simulations have four main phases as reported by de Oliveira et al., (2015) who conducted action research using experiential learning simulation with actors. The first phase is the theoretical content as stated by de Oliveira et al. The second phase is briefing the participants with instructions for performing the simulation, use of materials, simulators and the objectives of the simulation and the third phase is the performance of the simulation activity. The final phase, as reported by de Oliveira et al. is a debriefing discussion period after the simulation where reflection builds knowledge. De Oliveira et al. concluded clinical simulation to be effective in developing creative and critical-reflective skills through experiential learning.

Simulation can be used to bridge the gap between novice and competent healthcare professionals as noted by Galloway (2009). Galloway listed the various types of simulations as role-playing, standardized patients, partial task trainers, complex task trainers, integrated simulators (mannequins), full mission simulation, and formal reflective debriefing. Role-playing as reported by Galloway involved a clinical situation acted out by students with or without elaborate set-ups in realistic settings. Standardized patients as defined by Galloway are live actors with scripted answers acting a part in a simulation. Galloway defines partial task trainers as representing one task or part of a system or process such an intubation mannequin or IV arm for practicing specific tasks.

Complex task trainers Galloway describes as virtual-reality scenarios using complex sensors added to increase fidelity to partial task trainer systems. Galloway defined integrated simulators are whole body mannequins of adults, children or infants with computer integrations capable of responding realistically, in real time during a training scenario.

Full mission simulation as defined by Galloway is a team administered simulation that includes a pre-brief, task execution, and post simulation debriefing discussion to aid transference of information. Full mission simulations according to Galloway are carried out in a replicated scene such as an operating room or emergency room. Galloway concluded that simulation-based learning strategies can aid healthcare professionals in acquiring core competencies. These categories of simulations could be considered and developed as part of an alternative to clinical site rotations in NDT.

Pappas (2015) demonstrated that a *situated cognition apprenticeship* (SCA) could be adapted to online learning environments. The Pappas study provided detailed video instruction, reading, simulation exercises with coaching, scaffolding and discussion with peer and instructor feedback in the reflection phase, and the posttest assessment. The Pappas study described the use of situated learning as linked to activity, context and culture. Similar to experiential learning, it supports the theory that we learn by doing, experience, engagement, conversation and reflection according to Pappas. The Pappas study examined ways to use educational technology to achieve experiential or situated learning to support clinical and critical thinking skills to prepare students for a clinical internship or residency.

**Standards, Guidelines, Best Practices, and Resources for Simulation**

INACSL (2016) has published standards of best practice in simulation for nurses. These INACSL standards include recommendations for simulation design, outcomes and objectives. The INACSL standards also make recommendations for facilitation, debriefing, participant evaluation, professional integrity, simulation-enhanced inter-professional education (Sim-IPE), and a glossary of simulation terms.

In British Columbia, a Provincial Simulation Coordination Committee (PSCC) established in June, 2012, coordinates and advises health authorities and educational institutions in the advancement and development of simulation education (McDougall, 2015). The PSCC also provide advice about the use of simulation in assessments for certification, recertification and maintenance of certification (McDougall, 2015). Simulations use a device and set of conditions to present authentic problems for evaluation (McDougall, 2015). McDougall (2015) states that simulation positively impacts safety in fields such as the military, mechanics, industry, nuclear power, aviation, and aeronautical space development. McDougall also states that simulation positively impacts health professionals training by using learner-centered experiences in which the student exercises clinical patient care skills. A review of literature examining the use of simulation in British Columbian training and assessment of physicians and nurses was conducted by McDougall. The McDougall literature review supports the expansion of simulation use providing a risk-free learner environment for professionals to practice, expand and assess their skills. McDougall describes initiatives in Canada and the U.S, increasing the use of simulation in healthcare professional training and assessment. The outcome of the McDougall literature review supports the potential use of simulation training in neurodiagnostic technology clinical skill training.

Resources for the development of simulations are available through several organizations. The Society for Simulation in Healthcare (SSH) has published certification standards and accreditation standards (SSH, 2017). The National League for Nursing (NLN) published a vision for teaching with simulation (NLN, 2014) in which the league endorses the substitution of up to 50% of traditional clinical experiences with simulation. The NLN requires conditions comparable to the study (Hayden et al., 2014).

The Simulation Innovation Resource Center is a website associated with the NLN and provides information and resources. The leadership of the NLN developed a program for simulation educators in 2014 (Hayden et al., 2014). The NLN noticed a lack of common language and terminology and built on Benner's five stages of clinical competence for nursing (Benner, 1982; Benner et al., 2010) novice-to-expert model and applied the levels of experience to simulation educator growth. Benner's stages of nursing are novice, advanced beginner, competent, proficient and expert.

The NLN's levels of simulation education begin with a novice's recognition that simulation supports the curriculum (Benner et al., 2010; Hayden et al., 2014). The second level, advanced beginner, is described as questioning his or her abilities to integrate aspects of the curriculum into scenarios. The third level, the competent, demonstrated the ability to develop scenarios that support curriculum themes and learner needs (Benner et al., 2010; Hayden et al., 2014). The proficient demonstrates the ability to identify curriculum needs that simulation can address and evaluate simulation's impact on outcomes (Benner et al., 2010; Hayden et al., 2014). Finally, at the expert level simulation developer demonstrates the ability to design a needs assessment and apply data to curricular change that includes complex inter-professional opportunities (Benner, 1982; Benner et al., 2010; Hayden et al., 2014).

Thomas et al. (2015) expanded simulation use by developing a theory-based simulation educator resource based on Benner's (1982) Benner et al. (2010) levels. These levels of simulation education could be adapted to NDT. The levels could provide a ladder for building simulations that address clinical skills.

Motola, Devine, Chung, Sullivan, and Issengerg (2013) conducted a review of literature to examine best practices in use of simulation for healthcare education. Examples were compiled to help educators implement simulation into educational programs. The guide compiled by Motola et al. reviewed topics concerning use of simulation, curricula integration, and examines challenging aspects of simulation development. The Motola et al.'s literature review examined implementation plans and achieving consensus with faculty and administrators. Matching the appropriate objectives with simulation, providing instruction for students and faculty, generating feedback and debriefing participants, and the need for perpetual evaluation of the program effectiveness were reported by Motola et al. The Motola et al. review concluded that practice through deliberate repetition, mastery learning, range of difficulty, capturing clinical variation, and individualizing learning are essential elements of simulation. According to Motola et al., when participants are actively, not passively, involved in learning the aspect of teamwork becomes important. Simulated environments such as the emergency room, operating room and intensive care units, are the future of simulation in healthcare education as projected by Motola et al. Detailed development guidelines and best practices inform future educators of the potential use of simulation in NDT and other allied healthcare education.

The usefulness of human patient simulation mannequins in simulations for nursing clinical training was explored in an international Delphi study by Arthur et al., (2013) with the goal of establishing guidelines for quality simulation. The guidelines in the Arthur et al. study addressed pedagogical principles of aligning simulations to the curriculum goals and objectives. Providing orientation for participants is essential. Establishing simulation fidelity and ensuring knowledge base of staff performing simulations before student participation is important before engaging students. Conducting immediate post-simulation debriefing and reflection exercises for students results in better learning outcomes according to Arthur et al. These guidelines can be adapted or used as a template for future use of mannequins for simulation.

In an effort to examine knowledge transfer in nursing students through simulation Schott and Cook (2016) explored theories and uses of simulation in the literature. Theories noted in Schott and Cook literature review included Kolb (1984) four-stage learning cycle of experiential learning. Also noted were the NLN (2014) and Jeffries (2008) simulation framework of five concepts for simulation design involving the simulation facilitator, participant, educational objectives, instructional design and expected outcomes. For simulation scenario planning the INACSL standards of best practice in simulation were recommended by Schott and Cook. The INACSL standards recommend increased use of simulation and establishment of additional nurse residency programs. The INACSL standards noted the lack of analysis of what features of simulation impact transfer of knowledge into practice, in nurse residency programs according to Schott, & Cook.

King, Liu, Stroulia, and Nikolaidis (2013) performed a mixed methods study of the use of simulation virtual clients on an information communication technology (ICT) device or tablet. The tablet was used to address challenges in workflow and provide skills training to healthcare aides (HCAs) working in rural and suburban Canada (King et al., 2013). Fifty-three participants were surveyed, interviewed and placed into focus groups for discussion, including 32 HCAs according to King et al. The King et al. study extracted key themes from the focus groups including changes in attitudes toward tablets, positive and negative feelings about the use of technology. The King et al. study also observed better communication within the healthcare team, and the improvement of client care. There was also a positive influence on recruitment of new HCAs into the workforce, improved retention and greater potential for recognition noted by King et al. Pre-training, in the King et al. study, the positive comments about the use of the tablet ranged from 22-42% but after training using the simulated client, 68% of participants wanted to learn more about tablets. The King et al. study concluded that tablets did improve HCAs workflow and simulation via the tablet was an effective approach to providing training, build confidence and expanding skills.

**Instructional Design of Simulations**

Coming from an educational instructional design perspective, Romero-Hall (2016) defines computer-based simulations as providing learners with the ability to interact with or manipulate a model or system representing a realistic process. The process as reported by Romero-Hall should aid conceptualization of complex or abstract concepts, with learning objectives accomplished through simulation interaction, and decision-making. In Romero-Hall's summary of key instructional design elements she explains that distance learning simulations can provide a platform for team building among students from a wide range of geographic locations.

Strategies for good simulation design contain four elements: model, scenario, interface and fidelity, as described by Romero-Hall. Romero-Hall states that models should be as realistic as possible and allow learning through manipulation of elements of the model. When designing the scenarios, critical elements, learning objectives and rules should work together to promote the use of pre-existing knowledge and build on what is known as described in the work of Romero-Hall. A question at the start of a simulation scenario can create an expectancy within the learner's mind described Romero-Hall. There should be tools within the simulation interaction that help the learner arrive through open-ended discovery at the target knowledge or skill but stop short of being overwhelmed by cognitive load stated Romero-Hall. This may be accomplished stated Romero-Hall by providing guidance in the form of prompts or hints to learners when their progress wanders off the path to learning.

Advancement should depend on mastery of specified objectives specified Romero-Hall. Scored assessments, conforming to recommendations by Romero-Hall, should follow with feedback to the student and simulation interface should be intuitive and provide learner control, and verbal or visual engagement. Multimedia contiguity is accomplished by placing objects used in manipulation in proximity to minimize visual scanning by the learner stated Romero-Hall. Virtual simulations need dictionaries, glossaries, advice and help sections with easily identified icons or buttons as noted by

Romero-Hall and errors made by the learner should be accessible after the simulation. Fidelity or the level or realism, according to Romero-Hall, does not have a linear relationship with the quality of learning; the fidelity should begin low and basic with novice learners and possibly increase with proficiency.

A pedagogical model for simulation-based learning in healthcare was the goal of a mixed-methods design-based research in a case study by Keskitalo and Ruokamo (2015). The Keskitalo and Ruokamo study was conducted at Stanford University involving nine facilitators and 25 students. The study was based on the original research of Keskitalo, Ruokamo, Vaisanen, and Gaba (2013) conducted at the simulation center of Arcada University of Applied Sciences in Helsinki, Finland. In the Stanford study by Keskitalo and Ruokamo (2015), data were collected from five courses. The students were anesthesia residents in the second-year and third and fourth-year medical students participating in an anesthesia internship studying anesthesia crisis resource management (Keskitalo & Ruokamo, 2015). Activities were performed as a group.

The researchers developed a design framework for simulation called the Facilitating, Training and Learning Model (FTL) based on a socio-constructivist and socio-cultural perspectives on learning (Keskitalo & Ruokamo, 2015). The steps in the FTL model begin with pre-activities of choosing the right resources, introduction of the simulation to the facilitators and students, briefing the students on the scenario including hands-on time (Keskitalo & Ruokamo, 2015). The Keskitalo and Ruokamo initial presentation begins with the scenario when the learner focus is active, and the facilitators oversee the process. Then the debriefing is conducted. The debriefing is where most of the learning happens; then during post-activities new knowledge is integrated and the process is evaluated (Keskitalo & Ruokamo, 2015).

**Virtual reality simulations.** Virtual reality simulation use in radiography education was evaluated in a study by Shanahan (2016) at the School of Health and Biomedical Sciences, RMIT University, in Australia. The study used activity theory and Vygotsky's model of learning (Vygotsky, 1981) mediated by tools as the theoretical framework. Shanahan surveyed 84 students after participation in a virtual reality simulation. One focus of Shanahan's study was to evaluate virtual reality simulation as a tool to provide clinical experiences that may be difficult to achieve through any other means such as over exposure to radiation. Students overall prefer the use of simulation working alone. As a group the students showed some preference to the instructor-led simulations. The university plan to expand the use of virtual reality simulation in future academic years (Shanahan, 2016).

Virtual Environment for Radiotherapy Training (VERT) has been used successfully by London South Bank University (LSBU) for both technologist before their clinical placements and for patient education (Stewart-Lord, 2016). Radiology technology students are provided a week of direct experience with instrument controls without a patient present, which increases confidence in clinical skills (Stewart-Lord, 2016). Simulation in healthcare provides realistic, risk-free clinical experiences in which participants can practice problem-solving, decision-making and teamwork skills (Stewart-Lord, 2016). Defined metrics in the Stewart-Lord (2016) study allowing the trainer to control the complexity and individual feedback is essential. The positioning of patients by radiology technologists requires spatial awareness skills to perceive three dimensional (3D) relationships, and recognize anatomical elements on images in axial, sagittal and coronal planes. This is similar in complexity to NDT pattern recognition skills and electrode placement skills. VERT allows a safe trial of instrument controls without burdening clinical departments, VERT allows students to develop both interpersonal and technical skills (Stewart-Lord, 2016).

Goulding, Kay, and Li (2016) used a mixed-methods approach to study the effectiveness of an online virtual lab as a preparatory tool for allied health students taking medical laboratory science program in clinical microbiology courses. Participants in the Goulding et al. (2016) study included 64 university students in Oshawa, Canada, in their second, third and fourth years. The virtual lab simulated identification of bacteria using videos and images of expected reactions. Students reported that the virtual lab made skill acquisition both faster and easier by enabling students a visualization of procedures and reactions. This was effective in bridging the gap between theoretical or procedural knowledge and laboratory experiences.

Placing the virtual laboratory experience after the theoretical didactic training creates a low risk, low cognitive load learning environment. It is accessible to many students while hands-on teaching laboratories can only accommodate small groups. Students in the Goulding et al. study reported their perceptions that were tabulated with a 14-point Likert scale questionnaire and six open-ended questions. Ninety-seven percent of participants, in the Goulding et al. study, reported the use of images and viewing procedures before being asked to perform them aided learning. Positive comments from the open-ended questions totaled 159. Eighty-four percent of the Goulding et al. study perceived greater success in learning, and 77 to 78% perceived the virtual lab made learning faster and easier. Challenges in the Goulding et al. study included inability to skip around within the program, inadequate instructions and desire for more virtual test modules. The highest rated elements of the virtual lab were visual learning, authenticity, learner control and organizational design (Goulding et al., 2016).

Massive open online courses (MOOCs), a recent trend in education has opened access to many types of education including healthcare education. Potential methods for inclusion of virtual patients were explored by Stathakarou, Zary, and Kononowicz (2014) for the purpose for clinical reasoning skills. The courses used case scenarios either followed by collective evaluation or discussion subgroups in the Stathakarou et al. (2014) study. The subgroups were divided according to cultural or local healthcare practices in the Stathakarou et al. study. Short cases were used in the study for adaptive learning with virtual patients. In the short cases, focus could be on a few specific objectives rather than long involved case presentations as reported by Stathakarou et al. Digital badges were used to document achievement of objectives in the Stathakarou et al. study. MOOCs are useful in getting education to large numbers of individuals however providing certification of completion on a massive scale and documenting standards that meet requirements in all nations is challenging. Perhaps an international online school could provide NDT training in areas where an educational infrastructure does not yet exist.

Researchers at Loma Linda University constructed a mixed methods study using a standardized patient (actors) simulation and an objective structured clinical examination method (OSCE; Farahat et al., 2015). The Farahat et al. (2015) study was conducted with 37 students in a nutrition and dietetic course. OSCE cases were developed from real patients and each case included a primary and secondary nutritional problem in the

Farahat et al. study. Additional elements in the Farahat et al. study included religious and cultural diversity, requiring respectful science-based answers about new trends in dietetic care and interaction with another healthcare professional.

The OSCE in the Farahat et al. study began with a 15-minute orientation; 15-minute chart review; 20-minute simulated patient encounter; 25-minute charting exercise; 10-minute healthcare professional encounter; and 25-minute article reading. This was followed by answering related questions, 20-minute video observation of a dietitian interacting with a patient and 40-minute debriefing discussion in the Farahat et al. study. Participants in the Farahat et al. study, were given pre-test and posttests, surveys and interviews. OSCE improved participant's readiness to practice scores and 76% of students found it superior to the medical center experience of visiting patients and reviewing their charts. Seventy-eight percent found that collaboration with other healthcare professionals was helpful in preparing them for clinical practice in the Farahat et al. study. The significant finding in the Farahat et al. study was the success of improvement of perceived readiness to practice and the success of a structured learning objective-based simulation compared to visiting patients and viewing their charts. The complexity of the OSCE allowed multiple learning objectives to be addressed in one simulation as reported by Farahat et al.

**Leadership Training, Communication, Collaboration, and Teamwork in Simulation**

To integrate leadership training for third year undergraduate nursing students and combine theoretical and experiential learning McPherson and MacDonald (2017) paired simulation-based learning with an interpretive pedagogy. Their goal was connecting learning more directly to practice and linking theory to action according to McPherson and MacDonald. Participants in the McPherson and MacDonald study were given a 15-page guide explaining how the simulation was designed, philosophy behind simulation. The guide described the advantages of simulation, objectives of the simulation, topics to be addressed, and simulation development plan. Also included in the McPherson and MacDonald study guide was a confidentiality agreement, evaluation rubric, learner self-evaluation and a sample of the debriefing.

Ten teams of five students each participated in the one-day (three hour) class simulation in the study. The McPherson and MacDonald study participants were given reflection time, then the class was debriefed as a group allowing shared learning for each student's experience. Student self-evaluations noted an opportunity to apply what they had learned in theory, professional transformation, deeper thinking and a multi-perspective experience reported McPherson and MacDonald. Moving forward the McPherson and MacDonald want to integrate leadership exercises into all clinical simulations.

**Communication and simulation.** Analysis of efficacy of simulated patient use in nursing communication development and a review of the simulated patient recruitment and training process were the goals of a study by MacLean, Kelly, Geddes, and Della (2017). Their literature review examined 19 studies published between the years 2006 to 2016. The MacLean et al. review concluded that using simulation to aid the development of communication skills in nurses with challenging clinical interactions provides nurses with a strong foundation in communication skills. MacLean et al. recommend expanded use of simulated patients (SP) in a broader range of clinical contexts.

Core competencies for nurses including patient-centered care, interdisciplinary team work, evidence-based practice, quality improvement approaches and use of information technology were recommended by the Institute of Medicine [IOM] (Long, 2003). Using the IOM as their guide, pharmacy and nursing students at Wilkes University participated in an inter-professional education (IPE) laboratory cardiovascular patient scenario and were surveyed by Bolesta and Chmil (2014). Student participants surveyed by Bolesta and Chmil reported feeling more prepared for inter-professional communication and experienced slight improvement in overall scores. Perhaps interdisciplinary simulations could be a collaborative project for neuroscience nurses and neurodiagnostic technologists to broaden communication skills between the professions and share the work of simulation development.

**Teamwork or collaboration and simulation.** Teamwork experiences of nursing and medical students in a simulation-based inter-professional team training (SBITT) was explored in a concurrent mixed-methods study by Reime et al. (2016) in Norway. The 262 participants, in the Reime et al. study, were organized into 44 teams. Each scenario in the study was approximately 15 minutes in length and was video-taped. Each team in the Reime et al. study was observed and scored by instructors and followed up by focus-group interviews and a questionnaire. Two-hundred and sixty of the participants, in the Reime et al. study, were reviewed to evaluate the participants' perspective on the experience. Videos were shared with peers within the Reime et al. study for feedback and ratings.

During the Reime et al. study nursing students were observed to take a more passive observational role when paired with medical students. In the debriefing and evaluation of the videos Reime et al. participants gained insights as to their clinical skills as well as their posture, attitude toward co-workers, and ability to make their voice heard especially when patient safety was an issue. The Reime et al. study concluded that the simulation arena is powerful in transferring awareness as well as clinical and communication skills.

Simulations allow students to practice aloud, promoting clinical reasoning, share professional knowledge, building team and communication skills (Reime et al., 2016). NDT students must learn to communicate with many other healthcare professionals and simulations may be useful in learning professional communication skills. In the operating room NDT professionals must be willing to address the surgeon confidently. They must make their voice heard within a medical team while respecting other healthcare professionals.

A study at the University of Copenhagen compared the experience of single students (n = 14) to pairs or dyads of students (n = 16 or 8 dyads) using simulation-based training in ultrasound as reported by Tolsgaard et al. (2015). There were significant improvements in both groups after the simulation training with pre-tests and posttests evaluating performance in the Tolsgaard et al. study. The assessment used the Objective Structured Assessment of Ultrasound Skills (OSAUS). Results of the Tolsgaard et al. study showed Dyad training to be non-inferior to single-student training.  The Tolsgaard et al. study pass rate for the dyad students was 71.4 using the OSAUS test, while only 30% of the single trainees passed, though the dyad students had to share a simulation device and had only half the hands-on time. The success of the pairs of students in the Tolsgaard et al. study was attributed to learning from each other’s errors. The Tolsgaard et al. study of 30 participants had the goal of finding if pairing students was an inferior or non-inferior learning practice. Though the study was small and there was no examination of the interactions between the pairs of students it does confirm the positive experience of student collaboration in simulation training (Tolsgaard et al., 2015).

**Best practices**. Best practices recommendations for inter-professional collaborative simulation approaches in healthcare education was researched by Murdock, Bottorff and McCullough (2013). In their review of literature, Murdock et al. addressed high-fidelity human patient simulators, interactive didactic lectures, role play with and without standardized patients, and instructor modeling. Learning theories explored in the Murdock et al. studies reviewed included experiential learning (Kolb, 1984), social learning theory (Bandura, 1977), Jeffries' simulation model (Jeffries, 2008) based on constructivist learning theory and Burns and Anderson's (1993) theory of attention inertia. Murdock et al. concluded inter-professional simulations using different approaches can be valuable to enhance skills, knowledge, attitudes and collaboration.

Practical clinical examination skills training for medical students requires a high teacher-student ratio as reported by Kwant et al. (2015). Researchers at University Medical Center, Utrecht in The Netherlands conducted a quasi-experimental study that compared skills tests of first and second year medical students. The Kwant et al. study included 780 participants; each participating in two - four evaluation stations for a total of 2010 individual student scores. The Kwant et al. study took place in the academic years 2011 and 2013. The Kwant et al. study evaluated the use of mandatory e-modules for preparation of some students while others had text-based preparation.

Classroom instruction was the same for both groups in the Kwant et al. study. The control group in the Kwant et al. study received text-based exam preparation materials, while the interventional group received a mandatory e-module preparation for the physical-examination of patient's exam. The Observed Structured Clinical Exam (OSCE) for physical examination was used for student evaluation in the Kwant et al. study. Results of the Kwant et al. study showed that the exam scores of cohorts of students given access to e-module based preparation for practical clinical examination skills, were significantly higher. The Kwant et al. study students in cohorts given access to e-modules were compared to cohorts of students who were not given access to the e-module preparations before training sessions. The control group in the Kwant et al. study was instead given text preparation materials. OSCE must be passed before the start of clinical rotation for medical students.

Limitations and flaws of the Kwant et al. study, included the text preparation did not have the rich format and organization of the e-module which likely made it more engaging. The e-module was obligatory and tracked for participation, while the text preparation had no way to track participation in the Kwant et al. study. A more ethical study might have been constructed using historical score data from previous years and compare the scores of students who were *all* given the mandated e-modules. The assumption in education is that students within any class should be given equal advantages.

The Kwant et al. study claims to indicate the use of e-modules requires less instructor time, but the data does not compare an instructor led review for the exam. The study instead compared mandatory e-module reviews to text reviews. Each group experienced the same amount of instructor time in the classroom and instructor led practical instruction. The Kwant et al. study does however indicate the general value of obligatory e-module reviews prior to exams.

**Clinical confidence and simulation.** A 30-item voluntary survey of third and fourth-year nursing students evaluated their confidence, learning and satisfaction level after repeated simulation experiences in a study by Cummings and Connelly (2016). As the students in the Cummings and Connelly study progressed through the third and fourth year, they were exposed to additional simulations in a social cognitivist learning pattern. The survey revealed significant improvement in active learning, refinement of critical thinking and increased confidence (Cummings & Connelly, 2016).

Perceptions of nurses' clinical decision making was evaluated by Woda, Gruenke, Alt-Gehrman, and Hansen (2016) comparing different block sequencing of simulated learning experiences (SLEs). The qualitative descriptive study by Woda et al. surveyed 117 junior level nursing students. Themes from the Woda et al. survey were anxiety before the experience, decision making in real-time and increased patient care experience. The majority of students preferred SLEs prior to hospital learning experiences (HLEs), stating they felt more confident in making decisions after the simulation experience, the results indicate that the SLEs and HLEs can be offered in alternating sequences without impacting clinical decision making (Woda et al., 2016).

An understanding of the impact of emotions on simulation-based medical education was the goal of a mixed methods study in Finland by Keskitalo and Ruokamo (2016) using 175 volunteers in either anesthesia or emergency residencies. Pre-simulation Likert-type questionnaires addressing student expectations and post-simulation questionnaires addressing the emotions experienced in the simulation were tabulated in the Keskitalo and Ruokamo study. Emotions rated included enjoyment of studying, interest, enthusiasm, challenge, hopefulness, satisfaction, humor, cheerfulness and sense of community in the Keskitalo and Ruokamo study. Other emotions reported in the study included boredom, uncertainty, worry, stress, tension, jadedness, disappointment, shame, guilt, and sadness. Results of the Keskitalo and Ruokamo study showed prior to the simulation, participants felt positive emotions of interest, sense of community, and enjoyment of studying or negative emotions of uncertainty, worry. After the simulation, the positive emotions experienced were interest, sense of community and enjoyment of studying along with relief, satisfaction and challenge (Keskitalo & Ruokamo, 2016)

**Simulation and assessments.** Assessment of clinical reasoning competency is difficult due to the fact that clinical reasoning processes are essentially invisible. Fu (2015) assembled a panel of two other professors in Physical Therapy education from Long Island University to join him in development of an instrument called the Think Aloud Standardized Patient Examination (TASPE). Fu conducted a mixed methods study during the pilot of the exam. The three-person panel of faculty members assembled for the Fu study defined clinical reasoning as the ability to make clinical decisions in a hypothetical situation. These clinical decisions are made by using deductive reasoning, and knowledge according to Fu. Evaluations were made by observing the participant's narration of their own thought processes in the Fu study.

During the TASPE pilot study, students examined a standardized patient (actor) and verbalize the cognitive processes justifying their assessment and treatment plan, while a pair of examiners observed and scored their cognitive processes (Fu, 2015).

Twenty-eight student volunteers were evaluated in the Fu pilot study. Participants and examiners completed an anonymous survey about their experiences in the Fu study. The examinations in the Fu study were recorded on video for analysis. While the Fu study is limited in number and warrants further investigation, the results recommend the development of guidelines for examiner grading.

The Fu study participants supported the usefulness of the evaluation. A comprehensive system of clinical reasoning assessment would benefit a wide range of healthcare professions. The limitations in the TASPE system, used in the Fu study, involve the human factor in the evaluation by an examiner and the difficulty in standardizing an oral exam. To administer this type of exam on a wide scale many examiners would need to be trained, according to Fu. The format of the exam would need to be highly structured but even then, examiners would likely grade the same student differently because of their inability to separate their own standards from the standards set by the exam (Fu, 2015).

Wainwright and Gwyer (2017) discussed their perspective on the difficulty in assessing clinical reasoning skills and the use of standardized rubrics or tools. Such tools include (TASPE), *Diagnostic Thinking Inventory*, the *Self-Assessment of Clinical Reasoning Tool* and *the Health Sciences Reasoning Test (HRST).* Wainright and Gwyer recognized some issues with these testing tools. There are limitations when the ceiling of the tool is set too low, noted Wainright and Gwyer. When the ceiling is too low it is unable to measure the continued expanding process of clinical reasoning through experience and continuing education reported Wainright and Gwyer. Wainwright and Gwyer suggested collaborative efforts among researchers in different areas to establish a clear definition of clinical reasoning, identification of best practices and development of larger scale research projects. Wainwright and Gwyer identified experiences in didactic learning that focus on clinical reasoning development and strategies to be essential, so that students are prepared for clinical work. They suggest further research into effective ways to teach clinical reasoning across the curriculum (Wainwright & Gwyer, 2017).

The use of high-fidelity simulation-based assessments to evaluate a clinical competency was explored by Leigh et al. (2016). The Leigh et al. review of literature revealed that simulation-based assessment (SBA) has been used for medical and dental professions in the United States, Canada, United Kingdom and Israel. Leigh et al. noted the successful use of simulation in training for emergency medical services technologists, respiratory therapists, the American Heart Association, laparoscopic surgery, and advanced cardiac life support for primary certification of surgical residents.

According to the Leigh et al. review, other professions using simulation in assessments include anesthesia, and in the United Kingdom. the international medical graduates' linguistics exam. The goals, as stated by Leigh et al., of a simulation-based assessment for nursing or any allied health profession are to evaluate knowledge, skills, attitudes, problem-solving ability and clinical judgment. The process of development of a simulation-based assessment, as reported by Leigh et al., involves evidence-based scenarios that are reliable and valid tools, using best-practice guidelines, that are psychometrically sound, fair and reliable.

O'Brien, Hagler, and Thompson (2015) had the goal of establishing a guide to development of healthcare simulation scenarios for competency and performance assessment. An additional goal of the O'Brien et al. study was establishment of a process for optimization of validity of simulation-based assessments. The O'Brien et al. study reviewed literature to establish a formal process for development and validation of simulation scenarios.

The steps in development as O'Brien et al. extracted from literature were to first select the competencies or objectives to be addressed in the simulation scenarios and establish measurement parameters. Next, O'Brien et al. recommend the establishment of clear relationships between competencies and scenario content with the establishment of expected participant responses that demonstrate competence. The next step recommended by O'Brien et al. was to pilot the program with participants at various levels of competence and review the results by experts, making revisions as needed.

The O'Brien et al. research also identified a validation process beginning with defining the purpose of competency assessment and selecting an appropriate tool for targeted competencies. In addition, O'Brien et al. recommended a review of literature should be conducted to be sure the scenario is referenced to evidence-based practices and statistical research. Next a map of the scenario integration into the instrument or delivery script should be developed, so critical events are included, and identification of expected behaviors are established in accordance with O'Brien et al. At this point, O'Brien et al. recommended a draft of the scenario should be formally reviewed in depth by a validation team of experts.

O'Brien et al. suggested a modified Delphi process using an expert panel to review simulation scenarios and arrive through several rounds at a consensus. The Delphi process would minimize bias and support validity according to O'Brien et al. Finally, a pilot of the instrument should be performed with students, and the results reviewed by the team of experts in keeping with the process outlined by O'Brien et al.

A review of literature and narrative on the use of rubrics for simulation-based clinical learning for nursing students was conducted by Li (2016). The Li study combined Tanner's critical judgment model, which assesses clinical judgment using the four aspects, noticing, interpreting, responding and reflecting, with what she calls *Knowledge about Knowledge* (KAK). KAK, as described by Li, assesses component-based knowledge using seven different aspects. The Li assessments in KAK include declarative knowledge, cognitive knowledge, procedural knowledge, reasoning knowledge or systematic understanding, conditional knowledge, relational knowledge, and affective knowledge. Li combined Tanner's critical judgment and KAK which she has named *A's conceptual model of inventive simulation evaluation rubric*. Li introduced new assessments of knowledge and judgments in simulation-based clinical skill education.

Clinical evaluators in occupational therapy conducted a study to establish a database of common feedback comments as reported by Rodger et al. (2014). The comments were arranged by category to expedite direct feedback to students during clinical practice allowing more feedback from fewer instructors in the Rodger et al. study. The use of standardized terms in the Rodger et al. study has potential use in addressing scenario or simulation based clinical skills instruction and evaluation on a large scale in other allied healthcare professions. The Rodger et al. methods can streamline clinical education feedback and enhance or extend the capacity for interaction with instructors along with the ability to add personalized comments could expand the number of students an instructor could mentor.

Standardized terminology is well established in neurodiagnostics. NDT professionals routinely document patients' behaviors, responses, mental states, signs, and symptoms for physicians. These notations during testing include detailed descriptions of NDT data using standardized terms. Establishing standardized terminology for student evaluation feedback, as exemplified by Rodger et al. would provide for a more consistent evaluation process. Since the use of standardized terminology is integral to NDT, instructors would easily adopt such a method to evaluate students.

Benedict et al. (2017) studied practice readiness for 106 first year and 108 third year pharmacy students and 18 first year post-graduate pharmacy residents using a blended-simulation progress assessment. The Benedict et al. study was conducted at the University of Pittsburgh School of Pharmacy. The assessment used by Benedict et al. measured mastery of key professional outcomes using standardized patients, colleagues, virtual patients and high-fidelity mannequins. The students and residents in the Benedict et al. study moved through five stations that evaluated aspects of patient interaction. The aspects used in the Benedict et al. study included review of the patient's chart, assessment of key features of the illness defined in scenarios. The assessment used by Benedict et al. concluded with interaction with a standardized patient and high-fidelity mannequin. The Benedict et al. study rubric evaluated clinical decision making, attitudes of accountability, inter-professional and patient communication. The data in the Benedict et al. study was used to inform students of their progress, alignment with accreditation standards and curriculum development.

Nursing students in the Spanish University of Cantabria system were given clinical simulation scenarios as a learning activity and assessment in a study by

Alconero-Camarero, Gualdron-Romero, Sarabia-Cobo, and Martinez-Arce (2016). (Alconero-Camarero et al. reported 95% satisfaction with simulation-based learning activity and evaluation which led to positive communication, teamwork and learning from their own and other student's mistakes. The debriefing discussion after the simulation proved to be an important learning activity in the Alconero-Camarero et al. study.

**Empirical Evidence for Simulation in Clinical Skill Training**

Citing the National Organization for Nurse Practitioner Faculty's stance that the use of simulations for clinical practice lacks empirical evidence, Rutherford-Hemming, Nye, and Coram (2016) reviewed literature from 2010 to 2015. The Rutherford-Hemming et al. review was looking for research relating to the use of simulation in nurse practitioner (NP) education. The requirement that nurse practitioners (NPs) have a minimum of 500 hours of direct supervision in clinical practice was another focus of the Rutherford-Hemming et al. review. The Rutherford-Hemming et al. database search located 198 studies, which were narrowed to 15 studies to examine in depth. While empirical research evidence was not found, the review did locate a two-phase, qualitative, exploratory, mixed methods study using survey and interview data by Hawkins-Walsh et al. (2011). The Hawkins-Walsh et al. study surveyed 75 pediatric NP program directors. Sixty-five percent of U.S. NP programs participated in the Hawkins-Walsh et al. study. All the programs in the Hawkins-Walsh et al. study used simulation in their acute care pediatric training courses, and 85% used simulated patient scenarios in their primary care pediatric programs.

The National Council of State Boards of Nursing conducted a longitudinal randomized controlled study of pre-licensure nursing education (Hayden et al., 2014). The study was conducted by Hayden et al. (2014) and substituted clinical hours with simulation. The Hayden et al. study enlisted 666 first year students from ten U.S. training programs and randomized them into groups.

The Hayden et al. control group had traditional clinical experiences with no more than 10% simulation, the second group had 25% of their clinical hours replaced by simulation, and the last group had 50% of their clinical hours replaced by simulation. The Hayden et al. study concluded that there was no significant difference in the clinical competency determined by clinical preceptors and instructors. The Hayden et al. study also concluded no difference in nursing knowledge demonstrated on assessments and no significant differences in National Council Licensure Examination pass rates between any of the groups. The results showed substantial evidence that high-quality simulation experiences can be substituted for up to 50% of clinical practice hours (Hayden et al.). The students in the Hayden et al. study, were followed for six months into their clinical practice and no meaningful differences in clinical competency, clinical reasoning or overall readiness for clinical practice were noted.

Recognizing that clinical learning environments providing for clinical practice are diminishing, while knowledge and technical skill requirements for nurses are growing, Kang, Kim, Kim, Oh, and Lee (2015) studied the use of problem-based learning. The Kang et al. study evaluated 205 senior nursing students in a pediatric bronchiolitis course with one of three types of educational modules.

Experimental group one in the Kang et al. study was given access to problem-based learning (PBL) alone, experimental group two was given access to PBL with simulation and a control group was provided lecture-based instruction. Student scores, knowledge, confidence in skill performance and satisfaction were compared by Kang et al. Posttest knowledge was highest with group two in the Kang et al. study who experienced problem-based learning and simulation combined. The control group in the Kang et al. study scored significantly lower than the experimental groups. The Kang et al. group with the highest student satisfaction scores was group one, (PBL only group) followed by group two, the PBL and simulation group.

The Kang et al. study concluded that student satisfaction is an important part of motivation for continuing education. Use of educational technology innovations that cultivate critical thinking, clinical reasoning, assessment, technical skills and communication are becoming an important and useful part of all healthcare profession training according to Kang et al.

**Summary**

Historically, neurodiagnostic training has included a clinical site rotation to gain or enhance clinical skills and expose students to the clinical NDT laboratory environment (CoA-NDT, 2008). With the decrease of hospitals or clinics willing to serve as clinical sites for NDT students, schools have found it difficult to place all of their students in a clinical experience site (ASET, 2014). The goal of this review of the literature was to explore alternative methods for experiential learning to provide clinical reasoning skills using educational technology.

Experiential learning begins with an intellectualization of a situation by the student, brainstorming of strategies and reasoning to examine consequences of potential strategies, then implementation and testing the success of the strategies (Kalkbrenner & Horton-Parker, 2016). It can be done independently or collaboratively, in a simulated classroom environment, virtual environment or through the use of learning based on scenarios, cases, stories or problems (Kalkbrenner & Horton-Parker, 2016). It involves the use of realistic experiences, personal engagement, and cognitive processing that guide behavior and advance didactic learning into the realm of clinical practice (Dernova, 2015). An advantage of educational technology use in clinical reasoning skills is safety for patients, decreased stress for learners and inclusion of experiences uncommon or rare to clinical rotations (Kalkbrenner & Horton-Parker, 2016).

The first phase of the literature review was to examine clinical reasoning and critical thinking skills and their application in NDT clinical skills learning and assessment. Then the question of when clinical reasoning should be addressed in the curriculum sequence was explored. Falk et al. (2016) found no statistical difference in the order of theory and practice. Rivkin (2016) recommended early exposure to patient case presentations. Landeen et al. (2016) introduced clinical reasoning using problem-based learning in the first two years of a four-year degree in nursing. Gilliland (2017) also recommended early exposure to simulated patient case scenarios and think-aloud assessment for physical therapy students. Early exposure to clinical reasoning provides students with a foundational goal for making appropriate judgments as their education progresses.

Educational technology methods to explore clinical reasoning including problem-, case-, scenario-, story-based learning and simulation were examined. Use of these technologies to address clinical skills in other allied healthcare fields was the focus of the literature review. Standards, guidelines and best practices were also explored. Simulation's relation to experiential learning (Kolb, 1984; Schott & Cook, 2016). The use in nursing clinical skills has proven effective (Jeffries, 2008; NLN, 2014). Simulations should build on what is known using instructional design elements such as interactive manipulation by the student within the simulation helping the student learn through open-ended discovery (Romero-Hall, 2016).

Not all NDT clinical skills involve neurophysiology and instrumentation. Leadership, communication, collaboration and teamwork are essential for all allied healthcare professionals and an integral part of professional clinical skill development (McPherson & MacDonald, 2017). Simulation, case-, problem-, scenario- and story-based learning can be applied to collaborative and teamwork skills (MacLean et al., 2017). These methods can also assist the development of core competencies, professional responsibility, confidence, empathy and compassion for patients (Cummings & Connelly, 2016; Long, 2003). As with all learning student satisfaction is an important element. Nursing students at the University of Cantabria in Spain reported 95% satisfaction with stimulation-based learning, debriefing and assessment (Alconero-Camarero et al., 2016).

Clinical reasoning competency, though largely invisible, can be assessed using simulation in which the student is asked to think aloud sharing the thought processes involved with clinical decisions (Fu, 2015). Standardized rubrics as reported by Wainwright and Gwyer and high-fidelity simulation-based assessments as reported by

Leigh et al. were used to assess medical and dental students in the United States, Canada, the United Kingdom and Israel.

Other professionals using high fidelity simulation-based assessments include emergency medical technologists, respiratory therapists, and laparoscopic surgeons were reported by Leigh et al. (2016). High-fidelity assessments have been used for certification courses by the American Heart Association, according to Leigh et al. Linguistics exams, problem solving ability and clinical judgment have been evaluated using simulation assessments by Leigh et al.

A step-by-step process for optimization of healthcare simulation scenarios through review of the literature was combined by O'Brien et al. The process begins with competencies or objectives, measurement parameters, a clear relationship between competencies and scenario content, defining expected responses, piloting the program, expert review and making needed revisions as reported by O'Brien et al.

Empirical evidence supporting simulation in clinical skill training has been examined by the National Organization for Nurse Practitioner Faculty (Rutherford-Hemming et al., 2016) in a review of the literature from 2010-2015. While the Rutherford-Hemmings et al. study did not locate a quantitative empirical study, it did locate the qualitative Hawkins-Walsh et al. study (2011). Hawkins-Walsh et al. surveyed 75 pediatric nurse practitioner (NP) program directors with a 65% response rate. All the programs surveyed by Hawkins-Walsh et al. used simulation in their acute care pediatric training courses, and 85% used simulated patient scenarios in their primary care pediatric programs indicating growing use of simulation in nurse practitioner training.

The National Council of State Boards of Nursing's longitudinal, randomized, controlled study, conducted by Hayden et al. (2014) used simulation to replace clinical hours in pre-licensure nursing students. The Hayden et al. empirical study resulted in no significant difference in clinical competency or National Council Licensure Examination pass rates. Kang et al. (2015) compared a control group of students who were given traditional lecture-based instruction with a second group experiencing the same content enhanced with problem-based learning and the third group with problem-based learning and simulation. Posttest results confirmed the advantage of problem-based learning and simulation (Kang et al., 2015).

The decrease in available clinical learning environments and the increasing clinical reasoning skills required by allied healthcare professionals is fueling exploration of educational technology solutions (NLN, 2014; Raehl et al., 2013; Romig et al., 2017; U.S. Department of Education, 2010; Wilkinson et al., 2015). Nurses are expanding use of simulation (NLN, 2014). Fifty percent of nursing clinical skills can be taught using simulation according to the National League of Nursing (NLN, 2014). The WHO (2013) projects a shortage of healthcare workers in 2035 to be 12.9 million.

During the last decade, in the United States the number of graduates from existing accredited Neurodiagnostic training programs has a nationwide total of less than 300. The number of graduates has fallen short by more than 800 graduates per year (American Job Center, 2017; Bureau of Labor and Statistics, 2016; CoA-NDT, 2018). Every year that graduate numbers remain low the shortage grows.

The U.S. Department of Education's meta-analysis of evidence-based practices in online learning concluded student outcomes were modestly better in online learning than face-to-face classes (U.S. Department of Education, 2010). The experience of lecture presentation, demonstration, interaction, communication, discussion and sense of learning community are common elements of online learning (U.S. Department of Education, 2010).

When simulation, problem-, scenario-, case- or story-based learning are added, to online learning critical thinking or reasoning skills may develop in a virtual space (Schrader, 2015). Raurell-Torredá et al. brought to light that the use of simulation and case-based learning can present to students those cases seldom seen in clinical practice. Woda et al. noted how simulation before clinical practice increases clinical confidence. Pappas reported the use of situated cognition apprenticeships prepare students for clinical internships or residencies. The use of educational technology as an alternative to clinical site placement for professional training has been explored by allied healthcare fields similar to NDT. The use of educational technology to address NDT clinical skills training should be explored. In Chapter Three, a Delphi study is described to explore the use of educational technology to address NDT competencies.

# Chapter 3: Research Method

## Introduction

The purpose of this qualitative Delphi study was to explore innovative educational technology alternatives for NDT students to obtain clinical skills. By combining the knowledge of NDT professionals, NDT educators, and educational technology experts, I sought to achieve consensus about the potential use of educational technology in NDT clinical skills training. Clinical site shortages for training has limited enrollments in NDT schools, resulting in the closure of some schools (ASET – The Neurodiagnostic Society, 2016). If educators are able to use educational technology to provide clinical skills training online, NDT training programs may be able to increase enrollments and graduates. Larger graduating classes are needed to fill the increasing demand for qualified NDT professionals (American Job Center, 2017; CoA-NDT, 2017). Chapter 2 describes the exploration and success by other allied healthcare fields in applying educational technology methods to clinical skills and clinical reasoning. With clinical skills training obtained through the use of educational technology, graduates could follow their training with a year of residency for practical experience prior to credentialing exams.

I conducted a qualitative Delphi study to address the research question by bringing together experts from two different professions to explore the use of educational technology to address EEG technologist competencies (Dalkey, 1969). The neurodiagnostic experts brought to the study their knowledge and experience in neurodiagnostics while the educational technology experts brought their knowledge of the application of educational technology methods. The experiences of the educational technology expert panelists with techniques applied successfully in other professions may bring beneficial insights into possibilities for NDT education. The perspectives of these two groups of experts may illuminate an educational pathway incorporating the use of educational technology to expand the number of students, graduates, and trained professionals entering the field of NDT.

In this chapter, I describe the research method, question, and design approach for the study. I also discuss the role of the researcher, methodology, and instrument development. Procedures for selection of the expert panelists and the data analysis plan are described in detail. Credibility, transferability, dependability, and confirmability are addressed. In addition, I describe ethical procedures and methods to attain Institutional Review Board (IRB) approval.

## Research Design and Rationale

### Research Questions

RQ 1: What are the informed judgments of an expert panel of neurodiagnostic professionals, neurodiagnostic educators, educational technology experts, and educational technology educators about the use of educational technology in clinical skills training for neurodiagnostic technology students?

RQ 2: Does consensus exist, or can it be achieved through the Delphi process, among experts in educational technology and neurodiagnostic technology about the use of educational technology as clinical skills training for neurodiagnostic technology students?

The focus of the research questions is on exploring an approach to clinical skill training in NDT for which data are not currently available. The Delphi method, an aid to decision-making, is used in situations in which researchers explore possible solutions to problems requiring expertise from multiple sources and for which there are little existing data (Adler & Ziglio, 1996; Dalkey, 1969). Delphi methodology involves use of subjective, informed judgments, views, and opinions of expert panelists to examine potential solutions to a problem making the research primarily qualitative (Adler & Ziglio, 1996; Dalkey, 1969). As Adler and Ziglio (1996) noted, the Delphi study is used to explore ideas or problems in a creative way.

I asked panelists to provide ideas for new statements to be included in the next round of the instrument; doing so made the panelists sources of new information (Iqbal & Pipo-Young, 2009). In a Delphi study, panelists are asked during each round to reevaluate their previous ratings, based on feedback from the previous round. The goal is to evaluate areas of debate, controversy, or lack of clarity and either measure diversity or explore potential consensus (Iqbal & Pipon-Young, 2009).

I performed calculations of ratings data to evaluate the level of consensus. The calculations performed used an informed judgment which can change during the Delphi process. While the ratings data can be considered a quantitative element, it is not a fixed objective measurement of fact as is common in quantitative data (Rutberg & Bouikidis, 2018). Panelists received the median of the ratings during each round along with new statements or comments supplied by the panelists (Dalkey, 1969). Researchers use the Delphi method to explore future trends about which little data exists by exploring expert opinions that may evolve during the Delphi process as consensus is either achieved or not achieved (Adler & Ziglio, 1996).

The Delphi method is a qualitative research method used to determine if consensus of opinion exists or can be achieved through anonymous ratings of statements by a group of experts (Dalkey, 1969; Keeney & McKenna, 2011; Sekayi & Kennedy, 2017). The Delphi process enables expert panelists to transcend the boundaries of the status quo and project their expertise toward new possibilities (Keeney & McKenna, 2011). Delphi is an effective and efficient method to explore a problem that requires expertise in many areas (Adler & Ziglio, 1996). The anonymous nature of the expert panel minimizes the impact of group dynamics and dominant personalities often present in face-to-face meetings (Adler & Ziglio, 1996; Dalkey, 1969; Keeney & McKenna, 2011).

Delphi methodology explores the perspectives, perceptions, and predictions of a group of panelists about a topic for which there is a less than perfect knowledge base (Dalkey, 1969). An assumption of Delphi methodology is that group opinion is more valid than individual opinion (Keeney & McKenna, 2011). In a Delphi study, the communication is done anonymously via the Delphi instrument, so the words speak for themselves without the relationship, status, role, credentials, or influence of the speaker (Keeney & McKenna, 2011). A simple rating system is used to relate general consensus among the panelists while anonymity allows rating of statements in the Delphi instrument to be unbiased by the identities of the other panelists (Keeney & McKenna, 2011). When expert opinions are needed, a Delphi study provides an effective and efficient method of rapid data collection (Keeney & McKenna, 2011).

Delphi methodology has been used in similar studies with success. In a Delphi study in the Netherlands, Veenstra et al. (2017) explored healthcare professionals' views on clinical governance. Clinical governance is a phrase referring to a practice-based, value-driven system to improve and maintain quality patient care by encouraging teamwork, professionalism, and patient safety (Veenstra et al., 2017). The Veenstra et al. study, which was conducted at an academic hospital, included 24 professional panelists who rated the importance of 50 elements described in the literature as important to healthcare professionals. The elements rated in the Veenstra et al. study included a bottom-up approach, perceived ownership, leadership, continuing education, shared responsibility, teamwork and collaboration. The study was an exploration of whether those elements described in literature as important to healthcare professionals are perceived by working professionals as being of equal importance. The Delphi technique in the Veenstra et al. study provided the nurses and medical specialists a neutral ground to evaluate important elements, suggest additional elements, and reflect on results of each round.

Weise, Fisher, and Trollor (2016) conducted a modified Delphi study to define workforce competencies for Australian healthcare professionals working with patients experiencing intellectual disabilities and mental health issues. The Weise et al. study began with a framework that is familiar to the profession. By the second round, Weise et al. had identified 102 attributes across 14 domains. During the process the domains did not change, but 10 new elements were added, 38 elements were removed, and 44 elements were edited. The Weise et al. study began with a basic structure of domains and elements that was familiar to the workforce. The authors concluded that the Delphi method is useful when evaluating consensus in work force competencies and attributes.

Fletcher and Marchildon (2014) used Delphi methodology for qualitative, participatory, action research in Canadian health leadership restructuring. In the Fletcher and Marchildon study, the priority and focus were on identifying characteristics and best practices of successful leaders rather than achieving consensus. The modified Delphi process afforded the participants a confidential means to share ideas and increased involvement and investment in the project (Fletcher & Marchildon, 2014).

Quantitative researchers use a scientific approach to precisely measure a phenomenon using data to test and verify theories, according to McCusker and Gunaydin (2015). Qualitative approaches are explorational, examining perceptions, and are often used when there is a lack of clear understanding about problem or limited research, according to Rutberg and Bouikidis (2018). While a Delphi study can take an approach that is primarily qualitative or quantitative, the main focus of this study was the exploration of potential solutions to clinical skills training in NDT using expert opinion (Adler & Ziglio, 1996). As a result, a quantitative approach that primarily measures scientific data was not appropriate as the study was an exploration of perceptions and opinion. Future researchers may examine the use of educational technology using quantitative methods when outcomes data can be directly measured.

## Qualitative Tradition

The design of a qualitative Delphi study is an exploratory method identifying the nature and basic elements of a phenomenon as described by Habibi, Sarafrazi, and Izadyar (2014). According to Habibi et al. (2014), Delphi has no distinct place in the qualitative design traditions or approaches such as ethnography, grounded theory, phenomenology, ethnomethodology, case study, and action research. It explores complex multidimensional problems through a structured process of anonymous communication using multiple rounds of a Delphi instrument (Adler & Ziglio, 1996; Dalkey, 1969). Delphi is a method applied to problems requiring expertise from different disciplines addressing issues for which there are no direct data according to Habibi et al. Meaningful coherence is achieved by using an appropriate methodology to address the research question. Delphi is an optimal approach for exploring research questions that require multidisciplinary expertise (Adler & Ziglio, 1996; Dalkey, 1969; Sekayi & Kennedy, 2017). Delphi studies have been used in nursing and health research as noted by Keeney, Hasson, and McKenna, (2011). Keeney and McKenna (2011) described use of Delphi to explore clinical issues, funding, service requirements, patterns of disease, technology, education, and policy. Bringing together experts in educational technology with NDT professionals should provide a futuristic projection of educational technology use in NDT.

Traditional qualitative methods such as interviews or case studies would require data from existing schools who had addressed clinical skills using educational technology as an alternative to clinical site rotations. All accredited schools of NDT require a clinical site for students (CoA-NDT, 2012). Traditional qualitative methods such as interviews and case studies do not address the element of consensus that directly applies to the focus of the research question. Other methods do not allow the experts in educational technology and neurodiagnostics to address competencies and educational methods together, each bringing their perspective and expertise. Case studies investigate phenomena through an in-depth study in a specific environment (Ridder, 2017). Once this

Delphi is completed, the next step may be a case study to evaluate the approach of using educational technology in clinical skills training for NDT students.

The Delphi instrument consists of statements rated by expert panelists on a four-point scale as to their level of effectiveness. The first round of the Delphi Study presented a combined list of neurodiagnostic technology (NDT) graduate competencies (required learning outcomes) matched with educational technology methods. Two U.S. competency lists for EEG technology have been combined with competencies from Australia, Canada, and the United Kingdom. (ABRET, n.d.; ANS, 2014; ANTA, 2016; CAET, 2011; CoA-NDT, 2012). The panelists rated the statements for effectiveness. The Australian, Canadian, and U.K. competencies were selected because they are members of the Organization of Societies of Electrophysiological Technology (OSET) and their competencies are in English. Combining the competencies was done to provide a comprehensive English language list of NDT graduate competencies. While the competencies were all similar, there were elements of each set that were not included in the other competency lists.

## Role of the Researcher

The researcher's role is to find, invite, screen, and select members of the expert panel, combine international competencies and pair them with an initial educational method (Dalkey, 1969; Hsu & Sanford, 2012; Sekayi & Kennedy, 2017). In my research role, I produced the initial Delphi instrument and provided expert panelists with instructions and access. After the initial responses and new statements are submitted, the ratings were tabulated and incorporated new statements to be rated in the next round of the Delphi instrument. Results, new statements, and comments were shared with all expert panelists before the next round of the Delphi instrument. The ratings, new statements, and comments were not attributed to individual panelists.

The researcher has over 30 years of experience in the field of neurodiagnostics but is currently unemployed. The last three years she has been a full-time graduate student and not in a supervisory position with NDT professionals within the United States. In the past, she has been an independent contractor working with the national society, ASET – The Neurodiagnostic Society and ABRET, the credentialing organization, to develop online education and credentialing exams. She has no employees and supervises no one at present. She is currently president of OSET, the international Organization of Societies of Electrophysiological Technology. Associates from OSET were not invited to participate as panelists due to her role with OSET. She does volunteer work with the Global Organization of Health Education and is working with students in Ethiopia who are learning neurodiagnostics. There were no panelists outside the United States. The researcher serves on the advisory committee for the Institutes of Health Sciences so the administrator and director from the school were not invited to participate. There were no incentives or gifts provided to panelists. The panelists participated on a volunteer basis. Exclusion of international participants, administrators at the Institutes of Health Sciences and OSET council members or executive committee members guarded against inadvertent researcher influence.

I knew some of the participants professionally, but I was not in a leadership or supervisory role over any of the panelists. The nature of the Delphi process limits communication among the panelists to the Delphi instrument. The researcher is available to answer questions about the Delphi process or the purpose of the study but did not interview the panelists or engage in discussion of the rating of the Delphi statements. The researcher endeavored to remain an unbiased observer during data acquisition. After the expert panel begins the Delphi study, the researcher did not have contact with the panelists unless they had a question or needed prompting to complete the round.

## Methodology

### Participant Selection Logic

**Sources of panelists.** I sent invitations to panelists via email. Approval for the posting of a request for volunteers on the Society for Simulation in Healthcare (SSH) membership forum and the International Society for Technology in Education (ISTE) professional learning networks can be found in Appendix E. Educational technology professionals, fellow educational technology doctoral students from the Walden Participant Pool, and published authors were sources of educational technology experts. Neurodiagnostic professionals and instructors involved in NDT education or training were recruited.

**Selection of panelists.** Expert panelists were invited to participate based on their credentials and responses to questions in an invitation letter found in Appendix C. The questions evaluate their level of experience and understanding of educational technology use, expertise in neurodiagnostic technology (NDT), and commitment of the time needed to participate in the study. After screening, the panelists were sent information explaining the Delphi study process, their role, confidentiality, and time requirements. They were sent appropriate consent forms and verbatim IRB regulations. The target group for this study consisted of experts in NDT or educational technology, with willingness to give time and contemplation to address the complex problem of NDT graduate levels being impacted by the lack of clinical training sites. The sample size was 30, with 15 experts in NDT, and 15 experts in educational technology. Credentials were verified by the ABRET website and calling or visiting universities' websites for highest degrees for education experts.

**Sample size.** A sample size of 30 is the mean sample size for qualitative research (Boddy, 2016). The number of expert panelists in Delphi studies are generally between 15 and 20 (Hsu & Sanford, 2012) and rarely exceed 30 (Sekayi & Kennedy, 2017). A target goal of 30 expert panelists was chosen to include 15 individuals from NDT and 15 from educational technology. A target sample size of 30 would provide more than the customary 15 to 20 to guard against expected attrition which is always an issue in a Delph study and ranges from 28% to 40% (Keeney et al., 2011). The Delphi technique requires repeated rounds of ratings and participants can lose interest and drop out. Thirty participants agreed to participate. Twenty-four responded in round one. Polite email reminders were sent and phone calls to encourage panelists who did not respond. Twenty-two responded in round two. Nineteen responded in round three. The attrition rate of 37% falls in the range reported by Kenney et al. (2011) as common for Delphi studies.

The number of participants varies with the type of qualitative research, methodology, and epistemological perspective (Boddy, 2016). Sample size was also limited to some extend by the number of schools of Neurodiagnostic Technology and the relatively small population of professionals in neurodiagnostics. According to the American Job Center's latest reporting, there are an estimated 128,000 people in the neurodiagnostic technology profession (American Job Center, 2017). There are currently

23 accredited schools of NDT in the United States (ASET, 2018) and 13 unaccredited schools.

**Selection of Delphi panel**. Questions asked of potential expert panelists prior to the Delphi process examine their willingness to participate and give their time in an effort to achieve consensus (see Appendix C). Panelists' expert status was evaluated by their education and credentials, combined with work experience. There was a total of 30 expert panelists recruited but only 24 responded in the first round. It was anticipated that some participants would not complete the three Delphi rounds so starting with 30 panelists provides leeway for those who do not complete all three rounds. The number of Delphi expert panelists are generally between 15 and 20 (Hsu & Sanford, 2012) and rarely exceed 30 (Sekayi & Kennedy, 2017). Twenty-two panelists participated in round two and nineteen in round three. A balanced view of the problem and the use of educational technology is required so professionals in education technology and neurodiagnostic professionals brought expertise from both areas.

In the event that more than 30 participants come forward with appropriate qualifications, the number of participants may be increased with a balance of participants from both fields of expertise. If fewer than 30 participants volunteer to participate, additional efforts were made to recruit participants. If one field has a greater number of volunteers, balance was achieved by selecting NDT participants with greater number of ABRET credentials and educational technology participants with higher levels of education. Educational technology participants with healthcare experience were given preference over those without healthcare education experience.

**Procedures for Recruitment, Participation, and Data Collection**

Expert panelists were recruited via an email invitation (see Appendix C) after posting a request for volunteers to the SSH SimConnect forum, the ISTE professional learning network and Walden Participant Pool. If less than 15 panelists in NDT and 15 panelists in educational technology agree to participate, a second posting and round of emails was sent until 15 panelists agree to participate for each profession. The Delphi study began when a minimum of 30 panelists agreeing to participate have returned their consent form. If a greater number of participants volunteer, the number of panelists may have been increased as long as there is balance between the two professions. If more volunteers in the educational technology field come forward, those with the higher educational level or years of experience were invited to participate. Educational technology potential expert panelists with healthcare experience were given preference over those without a healthcare background. If more NDT professionals come forward to volunteer those with the greater number of NDT credentials or years of experience were invited to participate. No participants were solicited from the Walden community of students of faculty except through the Walden Participant Pool using a posted invitation describing the study.

**Step 1: Email Invitation.** Potential expert panelists were given information about the problem addressed by the study, the Delphi research tool, the role of an expert panelist, and the researcher's role in the process. Panelists are asked to commit their time and attention to the study, with an estimated one hour per week for three weeks.

**Step 2: Questions for Potential Expert Panelists.** Responses to screening questions were evaluated for level of expertise and time commitment. Those with highest levels of education and experience were invited. See Appendix C for email and screening questions.

**Step 3: Delphi Study Participant Consent Form.** Invited expert panelists are sent the official Walden consent. The consent form describes the nature of the research as a doctoral dissertation and explains there are no risks outside those of normal daily life and no monetary benefits to the study. Participant privacy and confidentiality is described. The phone number of the Walden representative who can answer questions is listed with the IRB number and expiration date. The participant was instructed to reply with "I consent" if he or she was willing to participate. The consent form is provided in Appendix E.

**Step 4: Instructions to Panelists.** The panelists rated the statements for effectiveness based on their experience and expertise. The rating system is a four-point scale with a rating of four meaning high degree of effectiveness and a rating of one meaning a low degree of effectiveness. After each statement, there is an opportunity for the expert panelists to insert a new statement or comment based on their experience and expertise. This allowed panelists to add a statement that would either better address the graduate competency in their opinion or an educational element that could be added to the competencies. The new statements were included in the next round of the Delphi study for rating by the expert panel.

The educational technology methods paired with the competencies include:

1. Asynchronous courses - online courses delivered asynchronously using textbook reading assignments, text documents, links to online information, video lectures, video demonstrations. The asynchronous courses may also

contain learning games, text and video assignments, discussions online in response to questions, interaction with faculty online. For assessments online quizzes and proctored exams may be used.

2. Simulation-based learning - interactive software simulations online.
3. Problem-based learning - student-centered practice of realistic problem-solving experiences.
4. Case-based learning – medical case examples with details from onset to diagnosis and treatment.
5. Scenario-based learning - student-centered experiential learning environment that places the learner into a specific set of circumstances calling for appropriate decisions.
6. Story-based learning - student-centered learning involving exposure to different perspectives in situations through reading, discussing or adopting different perspectives within a detailed story. Story-based learning is engaging and can add situational awareness and empathy to instructional design.

**Step 5: Access to the Delphi Instrument and Data Acquisition.** After the expert panelists agreed to participate and sign the consent form, they were sent email instructions to access the Delphi instrument on the Qualtrics online survey website (Qualtrics, 2018). Qualtrics is an online qualitative research survey tool. It was used to administer the Delphi instrument. The items in the Delphi instrument were numbered and any new statements provided by the panelists were added as a, b, c under the numbered statement. In this way the instrument statements were easily regenerated for the next round of the Delphi study.

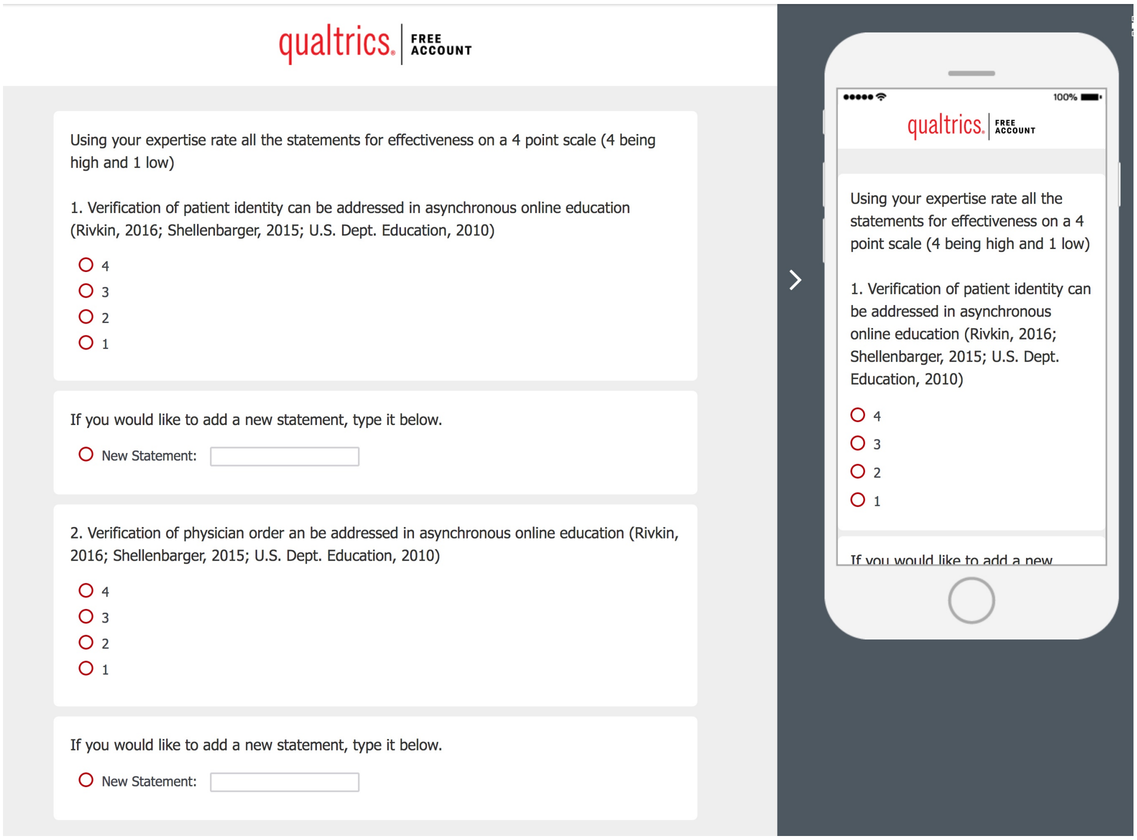


*Figure 1.* Sample of Qualtrics format.

**Qualifications of potential expert panelists.** Qualified expert panelists in neurodiagnostics had at least one neurodiagnostic credential and 5 or more years of experience training neurodiagnostic technologists either in a formal school environment, online formal or continuing education environment or in a clinical setting. The clinical setting could be either part of a clinical training site or on-the-job training of employees.

The screening of potential panelists consists of four questions in an initial email (See Appendix C). The expert panelists were asked about their experience with educational technology, online education, or distance education, and their experience with neurodiagnostics in the first two questions. All panelists had expertise and experience in either NDT or educational technology, but a few had experience in both fields. NDT credentials were verified on the ABRET website. Educational technology experts' highest degree was verified with the university. In the event that more than 15 expert panelists respond, the potential panelists with greater experience were included. When less than 30 panelists are recruited, additional SSH forum posts and emails were sent.

Educational technology experts were required to have at least a master's degree. The master's degree could be in educational technology, instructional design, or education with experience in online or distance education. Neurodiagnostic professionals were required to have at least one NDT credential and five years of experience training technologists in a formal, informal, or clinical environment. This included training conducted in the working environment. Potential panelists are asked to list their degrees, credentials, positions held, and years of experience.

The potential panelists must agree to the time commitment of a minimum of an hour per week for three weeks. The panelists were given a description of the Delphi process of rating statements in three rounds and optionally adding new statements. The panelists were given a description of an optimal Delphi expert panelist. The Delphi process requires expert panelists to transcend the boundaries of the status quo and project their expertise toward new possibilities. Ideal expert panelists approach the process from a relatively impartial standpoint of intellectual curiosity and openness to the perspectives of others. They make use of consensus building skills (Adler & Ziglio, 1996; Dalkey, 1969; Hsu & Sanford, 2012; Sekayi & Kennedy, 2017). The potential panelists were asked if they can work from a perspective of intellectual curiosity and consensus building as an expert panelist. The panelists must respond positively to the time commitment and working from a perspective of intellectual curiosity to build consensus.

***Inclusion criteria.*** Expert panelists were included based on their level of expertise in either neurodiagnostics technology or educational technology. Panelists must commit to working a minimum of one hour per week for three weeks.

Qualified expert panelists in educational technology must have a master's degree in either instructional design and technology, educational technology, or education with experience using educational technology. Educators in healthcare were preferred but not required. Doctoral students in educational technology and professionals holding a Ph.D. in education were accepted.

Qualified expert panelists in neurodiagnostics had at least one neurodiagnostic credential (ABRET registration in EEG or Evoked Potentials or certification in intraoperative neuromonitoring CNIM or long-term monitoring CLTM and five years of experience training neurodiagnostic technologists either in a formal school environment, online formal or continuing education environment or in a clinical setting. This includes on-the-job training. NDT professionals prove their skills in a series of registry and certification exams. Many NDT professionals hold multiple credentials, but some of the best educators may hold one credential. Few professionals in NDT hold advanced education degrees.

***Exclusion criteria.*** Potential expert panelists without the specified expertise in either NDT or educational technology were not included. Potential expert panelists unwilling to commit the time needed to complete the study were not included. Those not invited to participate were sent a polite email thanking them for their interest and time and explaining that more participants than needed volunteered.

***Verification*.** Verification of credentials was accomplished through the ABRET website, which is easily done. The researcher verified the highest degree of educational technology experts by contacting the school or visiting the school website.

***Confidentiality*.** Each expert panelist's identity was kept confidential throughout the Delphi process and after the study is completed. A brief list of credentials describing the combined expertise of the panelists was documented, but care was taken not to expose their identity. If panelists suspect the identity of other panelists, they are asked in their agreement to refrain from contacting them. Participants respond using a unique URL and a number was assigned to them. This allowed free expression of ideas via the Delphi instrument, removes some elements of group dynamics, and reduces the impact of dominant personalities (Adler & Ziglio, 1996; Sekayi & Kennedy, 2017).

## Instrumentation

**Data acquisition plan.** After screening and inviting the expert panelists to participate in the study, I gave them a consent form. After signing the consent form, they were given access to a Delphi instrument in Qualtrics. The Delphi instrument contains a combined list of EEG technologist graduate competencies paired with educational technology methods. Content validity is increased by the use of five sources of competencies from Australia, Canada, the United States, and the United Kingdom (ABRET, n.d.; ANS, 2014; ANTA, 2016; CAET, 2011; CoA-NDT, 2012). The statements also include references to studies using the educational technology in similar allied healthcare clinical skills instruction. The panelists were given four days to respond and responses were compiled with new statements or comments and circulated back to the panelists for consideration prior to the next round.

The ratings and new statements were circulated to the expert panelists after each round of the Delphi instrument and before the second and third rounds (Dalkey, 1969; Hsu & Sanford, 2012; Sekayi & Kennedy, 2017). This allowed the expert panelists to reflect on the level of effectiveness ratings and new statements or comments of the other expert panelists before rating the statements in the next round. There were three rounds of the Delphi instrument. It was expected that consensus would evolve in the process. If not, a fourth and final round could have been administered. The 70 combined competencies were addressed in 138 Delphi statements which have been paired with an educational technology method for the first round. In the first and second round, panelists may add new statements based on their experience and expertise. A complete list of Delphi statements combining graduate competencies with educational technology methods appears in Appendix D.

**Delphi instrument development plan.** The Delphi instrument is developed from a combined list of EEG graduate competencies [learning outcomes] from the United States (ABRET, n.d.; CoA-NDT, 2012), Australia (ANTA, 2016), Canada (CAET, 2011), and the United Kingdom (ANS, 2014). First round statements list the graduate competencies paired with an educational technology method. Citations are listed for each statement so panelists could research the referenced studies if they were so inclined.

**Sample of Delphi instrument statements.** Statements were rated by expert panelists in each of the three rounds. Panelists were given an opportunity to add new statements during each round that became part of the next round. Items are rated by the expert panelists on a four-point scale to reflect the effectiveness of the items in the statement. After each statement, there was an entry field called *New statement to add*. This entry field allowed panelists to add a statement that would either better address the graduate competency or an educational element was not addressed in the list. See Appendix D for the complete list. Table 1 includes a sample of Delphi statements for Round 1.

Table 1

*Sample of Delphi Statements for Round 1*

| | Delphi statement | Reference | Rating |
|---|---|---|---|
| 1 | Verification of patient identity can be addressed in asynchronous online education<br><br>New statement to add: | (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| 2 | Verification of physician order can be addressed in asynchronous online education<br><br>New statement to add: | (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| 3 | Verification of patient information can be addressed in asynchronous online education<br><br>New statement to add: | (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| 4 | Preparation of EEG Lab for patient testing can be addressed in asynchronous online education<br><br>New statement to add: | (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| 5. | Portable bedside EEG preparation can be addressed in asynchronous online education<br><br>New statement to add: | (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| 6. | Establishing patient rapport can be addressed using story-based learning modules<br><br>New statement to add: | (Paliadelis et al., 2015; Shaw et al., 2017). | 1, 2, 3, 4 |

*Note.* Delphi statements were developed using a combination of U.S. (ABRET, n.d.; CoA-NDT, 2012), Australian (ANTA, 2016), Canadian (CAET, 2011), and U.K. (ANS, 2014) competencies.

**Time frame.** The panelists were given access on Sunday and had 4 days to complete the round. Fridays the tabulations were calculated and then the results were distributed to the panelists for the next round on Sunday. The Delphi study lasted three weeks and a plan was in place if consensus was not achieved. A fourth round could have been added extending the study an additional week. This was not needed.

**Round 1.** The expert panelists were given access to a password protected Qualtrics site where a set of statements about the use of educational technology to address the 138 Delphi statements representing the 70 combined NDT graduate competencies. Some competencies require more than one educational technology method, so the methods needed are separated into additional statements. They were asked to rate the effectiveness of each statement on a scale of one to four where four is highly effective. After each statement, there were given an opportunity for the expert panelists to add a new statement or comment.

**Round 2.** After adding the median ratings and new statements from round one, the panelists were given access to the second round of statements with new statements from round one added to Qualtrics. New statements were added as *a, b, c,* under the original statement. The panelists were encouraged to review the tabulated results, reassess the statements, and add additional new statements if needed.

**Round 3.** Results from round two were shared along with any new statements and the expert panelists were asked to rate the statements again.

**Exiting the study.** The panelists were given a copy of the final results at the end of the study. They were cautioned to keep their participation in the study confidential not only during but also after the study has ended.

**Data analysis plan.** The primary goal of a Delphi study is a communication process, but the secondary goal is to measure consensus (Von der Gracht, 2012). The median score of each statement was shared with the panelists after each round along with any new statements provided by the panelists. The responses were documented in chapter four. The results were analyzed for consensus using the interquartile range (IQR) and quartile deviation. Consensus was defined as an interquartile range of equal to or less than one, as is cited in an overview for four- or five-unit scales (Birko, Dove, & Ozdemir, 2015; Von der Gracht, 2012). Consensus was achieved, so the process ended after three rounds. If consensus was not achieved, a fourth and final round would have been conducted. The data were analyzed using Microsoft Excel workbooks. The Delphi statements were listed in rows and the panelist's ratings were represented in columns. At the conclusion of the study, the participating panelists received a summary of the results of the study.

## Issues of Trustworthiness

There is a need for research in alternatives to clinical site placements for clinical skills training in NDT. As the demand for qualified NDT professionals reaches 1,100 per year (American Job Center, 2017; Bureau of Labor and Statistics, 2016) and the U.S. graduate totals are less than 300 per year (CoA-NDT, 2018), an exploration of alternatives is clearly needed. Expansion of long-term monitoring in the ICU and the use of NDT in intraoperative neuromonitoring has fueled recent growth but the need for more graduates has been an issue for many years (ASET, 2014; CoA-NDT, 2018). Exploring the use of educational technology to address as many clinical skills as possible may provide a pathway into the field without the need to place each student in a clinical site.

Combined possibly with workshops and a post-graduate residency for experience before credentialing exams, this pathway may lead to easing the entry into the field and greater numbers of graduates from the existing training programs.

**Credibility**

Credibility is addressed in this Delphi study by combining competencies from the U.S. [ABRET, n.d.; CoA-NDT, 2012], Australia, Canada and the U.K. (ANTA, 2016; CAET, 2011; ANS, 2014). Experts from NDT and educational technology were recruited within the United States. Ratings by expert panelists were combined with new statements provided and shared with the expert panelists before the next round of the instrument. The ratings, new statements and comments were not attributed to individual panelists. While the anonymity of the expert panelists reduces the impact of dominant personalities and group dynamics, there still could have been some pressure felt by the expert panelists to go along with the majority. The opinions of the panelists directed the research and the outcomes were reported unedited by the researcher.

**Transferability**

This research study has the potential to provide significant contributions and insights for educators in the field of neurodiagnostic technology and other allied healthcare professions. Schools may be able to expand enrollments thus sustaining the future success of the schools financially. Providing more NDT professionals means better quality care for patients with neurological disease or injury. While this study is focused on NDT, the results may be helpful to other allied healthcare professions with a shortage of clinical sites.

## Dependability

The selection of the expert panelists was the most important step in dependable results. By using experts in the field of NDT and the field of educational technology, expertise from both fields are included in the Delphi study. Combining the graduate competencies from Australia, Canada, and the United Kingdom with the ABRET practice analysis and CoA-NDT graduate competencies from the United States provides greater dependability through expanding the number of NDT professionals involved in competency development.

## Confirmability

Delphi responses were automatically documented to confirm their accuracy using Qualtrics (2017), an application service provider. Qualtrics archived the data and performed some data analysis. Qualtrics provides a highly confidential, secure platform, and does not disclose any data to third parties. Qualtrics is evaluated for vulnerability by a commercial security provider (Qualtrics, 2017). Expert panelists were sent a link that is password protected. Once submitted, the instrument does not reopen.

## Ethical Procedures

Ethical considerations in the research include requiring that the panelists' identity remain confidential throughout the research and after the conclusion of the research. Avoidance of researcher bias being injected into the process was guarded and the researcher journaled during the process to monitor personal views and evaluate the results. The initial pairing of competencies and educational technology methods were done by the researcher but could be changed by the opinions of the panelists. The researcher provided references of the different types of educational technologies used in similar ways in other professions for each Delphi statement.

I was granted permission to use the Society for Simulation in Healthcare's online forum and the International Society for Technology in Education's professional learning networks to request volunteers to serve as expert educational technology panelists. A simple request for volunteers was posted along with the need for confidentiality about their participation. The documents are in Appendix E. Those responding to the request were sent the invitation email shown in Appendix C. If invited to participate, those who responded received the consent form as prescribed by Walden University. When they return the signed documents, they were enrolled in the study.

Walden University's IRB cleared the research before panelists were invited or data were collected. The nature of the data, ratings of educational technology effectiveness in addressing EEG technology competencies, are not sensitive. All data remained confidential during acquisition and reporting. Only the researcher knew the identity of the panelists. A number was assigned to identify each panelist before the data were analyzed. The panelists' names did not appear in the study or in any publication. Panelists were not exposed to personal risk beyond the risk of normal daily life. As with all research involving participants, some participants did not complete the study. A sampling size of 30, rather than the usual 15 to 20, panelists provided a cushion in case there was attrition. The data collected consisted of opinions about effectiveness of the use of educational technology to address job competencies. Nothing potentially harmful to the participants either physically, professionally or emotionally is anticipated. In the event that a panelist brings forward an issue the panelist would have been referred to an appropriate resource. The data were protected to preserve the confidentiality of the study, which provides a neutral medium for rating effectiveness of educational technology methods to address competencies. The data was kept on the researcher's password protected desktop computer, in a password protected, file and will be destroyed after ten years. In the email invitation to participate, panelists were told that confidentiality is an important part of the Delphi process. Panelists were cautioned not to discuss their participation in the study during or after completion of the study, even if they suspect the identity of other participants.

**Social Change**

Walden's mission of social change is addressed in this research by focusing on solutions for the shortages of NDT professionals trained in the U.S. Exploration of educational technology methods to address clinical skills may provide an alternative pathway for NDT training. If clinical skill training could be addressed by means of technology as an alternative to requiring a clinical site, schools of NDT could expand enrollments and provide more qualified professionals. Patients with neurological disorders, sleep disorders, neurological injury, or requiring orthopedic or neurosurgery would have better access to neurodiagnostic care. Schools of NDT would be more financially sound with larger enrollments and graduates. The need for a clinical site for every student has resulted in potential students being turned away and the number of clinical sites has limited enrollments resulted in school closings. Exploring solutions to this problem using an expert panel may result in providing insights and a new pathway to supplying the NDT field with professionals now and into the future.

## Summary

In this Delphi study, experts were recruited from the neurodiagnostic technology and educational technology. Experts panelists were invited on the basis of their education, credentials, and experience. The expert panel rated statements linking competencies to educational technology methods for effectiveness, based on their expertise and experience. The panelists were given an opportunity to introduce new statements after rounds one and two. The median score of each statement was shared with the panelists after each round. The goal is to come to a consensus on the use of educational technology in clinical skills training for neurodiagnostic technologists performing electroencephalography. In chapter four the results of each round of the Delphi study are reported and tabulated. The results are evaluated for consensus using interquartile deviation.

# Chapter 4: Results

The purpose of this qualitative Delphi study was to explore innovative educational technology alternatives for NDT students to obtain clinical skills. By combining the knowledge of NDT professionals, NDT educators, and educational technology experts, I sought to achieve consensus about the potential use of educational technology in NDT clinical skills training. The study addressed the need to find alternatives to clinical site training. The shortage of clinical sites has potentially limited the number of student enrollments and graduates of NDT schools. The research question guiding the study asked, what are the informed judgments of an expert panel of NDT professionals and educators, educational technology experts, and educators about the use of educational technology in clinical skills training for NDT students. The second research question asked if consensus exists or could be achieved through the Delphi process, among experts in both fields, about the use of educational technology in NDT clinical skills.

This chapter includes an overview of the research process and summary of results. Panelists rated statements on a scale of 1-4, with 4 being high. Consensus was measured using interquartile deviation of ratings in the third round. The mean of ratings from each of the three Delphi rounds was used to identify the collective effectiveness rating for each of the statements pairing competencies with educational technology methods. The panelists interjected 59 new statements, and these were rated by the panel in the next round. All statements with a rating of less than 3, resulted in new statements using a different educational technology method and elevated the rating to above 2.95.

## Setting

Recruitment of experts using postings online with the Society for Simulation in Healthcare resulted in only one volunteer expert panelist. Posting on the forums for the International Society for Technology in Education and Walden University participant pool resulted in no volunteer participants. To successfully recruit participants, I sent a personal e-mail invitation to educational technology experts who had published in educational technology journals or held positions as educators or developers of educational technology. Neurodiagnostic technology participants were much easier to recruit because many know of the shortage of qualified neurodiagnostic technologists.

The expert panelists participated in the Delphi study using Qualtrics online software. The experts were never convened in one place. I gathered their responses online in Qualtrics, and their communication during the study was limited to responses and new statements added to the list of competencies and online educational methods. The online gathering of data was helpful in maintaining confidentiality.

## Demographics

The expert panelists were predominantly female. There were two male expert panelists in the neurodiagnostic group and four men in the educational technology expert panelists group. Of the 556 neurodiagnostic professionals responding to the ASET salary survey (ASET, 2015), 28% were male and 72% female. The National Center for Education Statistics (2011) reported that 76% of public-school teachers are female and 56% have a master’s or higher degree. The expert panel was therefore relatively representative of the professions. I did not gather other demographic data such as age or location. Selection was based on education and credentials in neurodiagnostics.

All recruited experts met the criteria for selection described in Chapter 3. Educational technology experts held a minimum of a master's degree in educational technology, instructional design, or education with experience in educational technology. Nine of the panelists had doctoral degrees, and six had master's degrees. Five of the NDT experts had a bachelor's degree. Twelve had ABRET registries in EEG, nine had ABRET registries in evoked potentials, six were certified by ABRET in long-term monitoring, and eight were certified by ABRET in intraoperative neuromonitoring. The NDT experts included 10 who had served or were serving on professional or credentialing boards, eight of whom served as officers. Five of the NDT expert panelists had served or were serving as program directors. The educational technology expert panelists included eight university professors, six directors of academic technology, one university "professor of the year," two editors of quarterly journals, one dean, and one CEO of a professional simulation development company. Several of the educational technology expert panelists were published authors and served on various educational professional boards.

## Data Collection

I sent 77 invitations to prospective panelists to which 30 replied accepting the invitation and returned signed consent forms. Of the 30 who agreed to participate, 24 participated in the first round reducing the sample size to 24, 22 in the second round, and 19 in the third and final round. Retention of experts was greater in the NDT half of the panel. Eleven of those completing the final round were from NDT and eight were educational technology experts. The greater retention of the NDT expert panelists likely reflected their awareness of the educational issues within the profession, the lack of clinical sites, and the shortage of professionals entering the field.

The Delphi instrument in Round 1 had 138 statements pairing the combined competencies with educational technology methods. With added new statements from the panelists, the final round contained 197 statements. At the start of each round, I sent links to the Delphi instrument in Qualtrics on Sundays with a completion target day of Thursday the same week. In Round 2, I added the mean of ratings from Round 1 to each statement for consideration by the panelists. Similarly, the mean of ratings from Round 2 was added to the statements for Round 3. The links were sent out on three consecutive weeks, starting on August 1st, 2018. Extra days were offered in the final round of the study to increase the number of responses. One statement was listed in Qualtrics twice by error but received similar ratings. Procedures in the competencies were not adequately explained in the statements involving evaluating the patient's state, electrical safety standards, calibration, managing data, activation procedures, the impetus for the study, and the narrow focus of the study. I concluded that additional information about these procedures was required for the educational technology expert panelists who were unfamiliar with them, unlike the NDT expert panelists. Clarifications of the statements were provided in the e-mail notifications to the panelists with a link to the next round of the study.

## Data Analysis

I exported data from Qualtrics in two formats. A raw data report was used to calculate the interquartile deviation of the third-round responses and a Microsoft Word document was used to gather the mean ratings of each round. The mean results of the three rounds and the interquartile deviation (*IQD*) as a measure of consensus are listed in Table 2. The raw data report listed the ratings of each panelist to each statement. The series of responses were selected in Excel and the equation applied to find the third and first quartiles, then IQD was calculated by subtracting quartile one from Quartile 3 and dividing by two [$Q\,3 - Q\,1 / 2 = IQD$]. Statements were rated for effectiveness on a scale of 1–4, with 4 being high.

The ratings were all above 2, and only eight statements were rated below 3 in any round. Seven of the eight statements rated below 3 rose to above 3 in subsequent rounds or had new statements introduced by the panelists with a different or enhanced educational technology method that scored above 3 in the next round. An example of this type of change was to add *interactive* to the description of the educational technology method. The only statement rating below a 3 involved coordination of a patient's ability to cooperate with activation procedures which had a mean rating of 2.95 in round 3. Ratings below 3 are underlined in Table 2.

## Evidence of Trustworthiness

### Credibility

Credibility was addressed in this Delphi study by combining competencies from the United States [ABRET, n.d.; CoA-NDT, 2012], Australia (ANTA, 2016), Canada (CAET, 2011), and the United Kingdom (ANS, 2014). A balance of experts from NDT and educational technology were recruited within the United States. Ratings by expert panelists were combined with new statements provided and shared with the expert panelists before the next round of the Delphi instrument. The ratings and new statements were not attributed to individual panelists. Anonymity of the expert panelists reduced the impact of dominant personalities and group dynamics. The opinions of the panelists directed the research and the outcomes were reported unedited by the researcher.

**Transferability**

This research study provides significant contributions and insights for educators in the field of neurodiagnostic technology and other allied healthcare professions. This study provides support for the use of educational technology to expand enrollments thus sustaining the future success of the schools financially. Providing greater numbers of trained NDT professionals would result in better quality care for patients with neurological disease or injury. While this study was focused on NDT, the results may be helpful to other allied healthcare professions in the same way research in other allied healthcare fields provided guidance for this study.

**Dependability**

The selection of the expert panelists was the most important step in dependable results. By using experts in the field of NDT and the field of educational technology, expertise from both fields is included in the Delphi study results. Combining the graduate competencies from Australia, Canada, and the United Kingdom with the ABRET practice analysis and CoA-NDT graduate competencies from the United States provides greater dependability through expanding the number of NDT professionals involved in competency development.

**Confirmability**

Delphi responses were automatically documented to confirm their accuracy using Qualtrics (2017), an application service provider. Qualtrics archived the data and performed some data analysis including the mean, standard deviation, and variance. Interquartile deviation (IQD = (Q3-Q1) / 2) was processed in Microsoft Excel. Qualtrics provides a highly confidential, secure platform, and does not disclose any data to third parties. Qualtrics is evaluated for vulnerability by a commercial security provider (Qualtrics, 2017). Expert panelists were sent a link that was password protected. Once submitted, the instrument does not reopen, thus protecting the data.

## Results

### Results by Round and Consensus

Table 2 lists the statements with the mean of ratings in round one (R1), round two (R2) and round three (R3) and the IQD of round three. Delphi statements were developed using a combination of U.S., (ABRET, n.d.; CoA-NDT, 2012), Australian (ANTA, 2016), Canadian (CAET, 2011), and U.K. (ANS, 2014) competencies and practice analysis lists. When new statements were suggested by the panelists the statements were entered as a., b., c. below the statement where they were entered and are designated with *NEW* before the statement. New statements begin to be rated in the round after they were suggested by panelists. Round 3 was extended due to the researcher attending a meeting. Consensus on all statements was achieved in round 3. Mean ratings less than 3 are underlined. Only one mean rating remained under 3, at 2.95 after the third round. Over the course of the study, 59 new statements were added by the panelists.

Table 2

*Delphi Results for Rounds 1, 2, and 3 Including Interquartile Deviation and Consensus*

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 1. Verification of patient identity can be addressed in asynchronous online education. | 3.5 | 3.57 | 3.74 | 0.25 | Yes |
| 2. Verification of physician order can be addressed in asynchronous online education. | 3.46 | 3.48 | 3.63 | 0.5 | Yes |
| 2a. NEW Verification of physician order can be addressed in scenario-based learning. | | 3.52 | 3.53 | 0.5 | Yes |
| 3. Verification of patient information can be addressed in asynchronous online education. | 3.46 | 3.62 | 3.58 | 0.5 | Yes |
| 4. Preparation of EEG Lab for patient testing can be addressed in asynchronous online education. | 3.25 | 3.24 | 3.53 | 0.5 | Yes |
| 5. Portable bedside EEG preparation can be addressed in asynchronous online education. | 3.13 | 3.05 | 3.32 | 0.5 | Yes |
| 6. Establishing patient rapport can be addressed using story-based learning modules. | 3.29 | 2.95 | <u>2.68</u> | 0.5 | Yes |
| 6a. NEW Establishing patient rapport can be addressed using interactive story-based learning modules. | | 3.29 | 3.16 | 0.25 | Yes |
| 6b. NEW Methods of establishing patient rapport can be demonstrated using story-based learning modules. | | 3.38 | 3.42 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 7. Explaining the EEG procedure in a manner appropriate to patient's age can be addressed using story-based learning modules. | 3.38 | 3.38 | 3.42 | 0.5 | Yes |
| 8. Explaining the EEG procedure in a manner appropriate to patient's culture can be addressed using story-based learning modules. | 3.29 | 3.1 | 3.21 | 0.5 | Yes |
| 8a. NEW Multicultural sensitivity training can be addressed using story-based learning modules. | | 3.33 | 3.21 | 0.5 | Yes |
| 9. Explaining the EEG procedure in a manner appropriate to patient's cognitive abilities can be addressed using story-based learning modules. | 3.17 | 3.14 | 3.21 | 0.25 | Yes |
| 10. Responding to patient and family's questions can be addressed in asynchronous online education. | 3.04 | 2.76 | <u>2.63</u> | 0.5 | Yes |
| 10a. NEW Responding to patient and family's questions can be addressed using story-based learning modules. | | 3.1 | 3.05 | 0 | Yes |
| 10b. NEW Responding to patient and family's questions can be addressed in interactive asynchronous online education. | | 3.29 | 3.21 | 0.5 | Yes |
| 11. Making appropriate referrals to other healthcare professionals when needed can be addressed in scenario-based learning modules. | 3.33 | 3.24 | 3.53 | 0.5 | Yes |
| 12. Explaining procedure for acquiring test results can be addressed in asynchronous online education. | 3.63 | 3.67 | 3.84 | 0 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 13. Respectful interprofessional collaboration and teamwork can be addressed in interactive simulation online. | 3.29 | 3.19 | 3.42 | 0.5 | Yes |
| 13a. NEW Interprofessional collaboration and teamwork can be addressed in team training in simulators. | | 3.57 | 3.63 | 0.5 | Yes |
| 13b. NEW The methods and application of respectful interprofessional collaboration and teamwork can be addressed in synchronous interactive simulation online. | | 3.38 | 3.68 | 0.5 | Yes |
| 14. The scope of practice of other allied healthcare professionals can be addressed with asynchronous online education. | 3.58 | 3.52 | 3.63 | 0.5 | Yes |
| 15. Managing workload and productivity skills can be addressed in asynchronous online education. | 3.04 | 2.86 | 2.89 | 0.25 | Yes |
| 15a. NEW Managing workload and productivity skills can be addressed in interactive asynchronous online education. | | 3.1 | 3.26 | 0.25 | Yes |
| 15b. NEW Managing workload and productivity skills can be addressed in problem-based learning. | | 3.48 | 3.63 | 0.5 | Yes |
| 15c. NEW Managing workload and productivity skills can be addressed in scenario-based learning modules. | | 3.43 | 3.53 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 16. Written and oral communication skills can be addressed in asynchronous online education. | 3.04 | 2.9 | 3.05 | 0.25 | Yes |
| 16a. NEW Oral communication skills can be addressed in interactive simulations. | | 2.95 | 3.16 | 0 | Yes |
| 16b. NEW Written and oral communication skills can be addressed in asynchronous online education with the proper assessment and opportunities to revise work to incorporate feedback. | | 3.33 | 3.58 | 0.5 | Yes |
| 16c. NEW Written and oral communication skills can be addressed in interactive asynchronous online education. | | 3.05 | 3.32 | 0.5 | Yes |
| 16d. NEW Written and oral communication skills can be addressed with scenario-based learning modules online. | | 3.14 | 3.21 | 0.25 | Yes |
| 17. Medical terminology can be addressed in asynchronous online education with audio/video recordings. | 3.83 | 3.9 | 3.79 | 0 | Yes |
| 17a. NEW Scenarios could be used to enhance and assess medical terminology knowledge. | | 3.62 | 3.79 | 0 | Yes |
| 18. Basic problem-solving skills can be addressed in asynchronous problem-based learning online. | 3.46 | 3.24 | 3.42 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 19. Conflict resolution techniques can be addressed in interactive simulations. | 3.58 | 3.38 | 3.47 | 0.5 | Yes |
| 19a. NEW Conflict resolution techniques and application can be demonstrated in interactive online simulations. | | 3.71 | 3.79 | 0 | Yes |
| 20. Activation procedure contraindication determination can be addressed in asynchronous online education. | 3.38 | 3.33 | 3.53 | 0.5 | Yes |
| 20b. Activation procedure contraindication determination can be addressed in interactive asynchronous online education. | | 3.62 | 3.68 | 0.5 | Yes |
| 21. History taking skills can be addressed in asynchronous online education. | 3.46 | 3.38 | 3.68 | 0.5 | Yes |
| 21a. NEW History taking skills can be addressed with scenario-based learning modules online. | | 3.67 | 3.79 | 0 | Yes |
| 22. EEG data management can be addressed in asynchronous online education | 3.54 | 3.57 | 3.79 | 0 | Yes |
| 23. Documentation of medications can be addressed in asynchronous online education. | 3.75 | 3.81 | 3.84 | 0 | Yes |
| 24. Documentation of time of last meal can be addressed in asynchronous online education. | 3.83 | 3.86 | 3.89 | 0 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 25. How to document the time of last seizure or symptom can be addressed in asynchronous online education. | 3.75 | 3.67 | 3.89 | 0 | Yes |
| 26. Evaluation of patient state can be addressed in asynchronous online education. | 2.96 | 2.57 | 2.95 | 0 | Yes |
| 26a. NEW Evaluation of patient state can be addressed in interactive asynchronous online education. | | 3.14 | 3.21 | 0.5 | Yes |
| 26b. NEW Evaluation of patient state can be addressed in problem-based learning modules online. | | 3.29 | 3.21 | 0.5 | Yes |
| 27. Documentation of patient state can be addressed in asynchronous online education | 3.5 | 3.38 | 3.21 | 0.5 | Yes |
| 28. Documentation of skull defects or anomalies can be addressed in asynchronous online education | 3.42 | 3.43 | 3.68 | 0.5 | Yes |
| 29. Recognition of the need to make modifications to the 10-20 System can be addressed in asynchronous online education. | 3.38 | 3.19 | 3.42 | 0.5 | Yes |
| 30. Documentation of modifications to the International 10-20 System can be addressed in asynchronous online education. | 3.58 | 3.52 | 3.58 | 0.5 | Yes |
| 31. Patient electrical safety practices can be addressed in asynchronous online education. | 3.67 | 3.76 | 3.68 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 32. Digital neurodiagnostic instrumentation can be addressed in asynchronous online education. | 3.63 | 3.52 | 3.63 | 0.5 | Yes |
| 33. Application of digital instrumentation concepts can be addressed with problem-based learning online. | 3.38 | 3.43 | 3.58 | 0.5 | Yes |
| 33a. NEW Application of digital instrumentation concepts can be addressed with problem-based learning online, scenarios and simulations. | | 3.81 | 3.79 | 0 | Yes |
| 34. The role of a system reference in reformatting of recorded digital EEG data can be addressed in asynchronous online education. | 3.63 | 3.67 | 3.79 | 0 | Yes |
| 35. Use of montages can be addressed in asynchronous online education. | 3.5 | 3.38 | 3.53 | 0.5 | Yes |
| 35a. NEW Use of montages can be addressed with problem-based learning modules online. | | 3.62 | 3.74 | 0.25 | Yes |
| 36. Polarity can be addressed in asynchronous online education. | 3.75 | 3.71 | 3.89 | 0 | Yes |
| 37. Localization can be addressed with problem-based learning online. | 3.63 | 3.52 | 3.68 | 0.25 | Yes |
| 38. Calculation of voltages can be addressed with problem-based learning online. | 3.71 | 3.67 | 3.84 | 0 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 38a. NEW Calculation of voltages can be addressed with asynchronous online education. | | 3.62 | 3.74 | 0.25 | Yes |
| 39. Analog to digital conversion can be addressed with problem-based learning online. | 3.5 | 3.67 | 3.74 | 0.25 | Yes |
| 39a. NEW Analog to digital conversion can be addressed with asynchronous online education. | | 3.76 | 3.79 | 0 | Yes |
| 40. Impact of using electrodes of differing materials or length can be addressed in asynchronous online education. | 3.63 | 3.67 | 3.84 | 0 | Yes |
| 41. The integration of video monitoring with EEG recording can be addressed in asynchronous online education. | 3.5 | 3.38 | 3.68 | 0.5 | Yes |
| 41a. NEW The integration of video monitoring with EEG recording can be addressed with scenario-based learning modules online. | | 3.62 | 3.74 | 0.25 | Yes |
| 42. Basic equipment maintenance can be addressed in asynchronous online education. | 3.42 | 3.33 | 3.63 | 0.5 | Yes |
| 43. Use of specific equipment software can be addressed in asynchronous online education. | 3.38 | 3.43 | 3.63 | 0.5 | Yes |
| 44. Procedure for documenting system maintenance can be addressed in asynchronous online education. | 3.75 | 3.71 | 3.84 | 0 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 45. Neurodiagnostic terminology can be addressed in asynchronous online education with audio/video recordings. | 3.83 | 3.86 | 3.79 | 0 | Yes |
| 46. Recognition of normal and normal variant EEG patterns can be addressed in asynchronous online education. | 3.33 | 3.24 | 3.26 | 0.5 | Yes |
| 46a. NEW Recognition of normal and normal variant EEG patterns can be addressed in problem-based learning modules online. | | 3.62 | 3.42 | 0.5 | Yes |
| 47. Identification of EEG abnormal patterns with clinical correlates can be addressed in case-based learning modules online. | 3.42 | 3.43 | 3.42 | 0.5 | Yes |
| 48. Neuroanatomy can be addressed in asynchronous online education. | 3.63 | 3.67 | 3.84 | 0 | Yes |
| 48a. NEW Neuroanatomy can be addressed in interactive asynchronous online education. | | 3.76 | 3.89 | 0 | Yes |
| 48b. NEW Neuroanatomy can be addressed using educational technologies that incorporate multiple types of memory including visual and auditory. | | 3.57 | 3.79 | 0 | Yes |
| 49. Neurophysiology can be addressed in asynchronous online education. | 3.58 | 3.67 | 3.84 | 0 | Yes |
| 49a. NEW Neurophysiology can be addressed in interactive asynchronous online education. | | 3.62 | 3.84 | 0 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 49a. NEW Neurophysiology can be addressed using educational technologies that integrate different types of memory including visual, and auditory. | | 3.62 | 3.79 | 0 | Yes |
| 50. The metric system can be addressed in asynchronous online education. | 3.83 | 3.9 | 3.89 | 0 | Yes |
| 51. Medication effects on EEG data can be addressed in asynchronous online education. | 3.63 | 3.57 | 3.58 | 0.5 | Yes |
| 52. EEG correlates to adult neurological disorders can be addressed in case-based learning modules online. | 3.54 | 3.52 | 3.58 | 0.5 | Yes |
| 53. EEG correlates to pediatric neurological disorders can be addressed in case-based learning modules online. | 3.54 | 3.57 | 3.47 | 0.5 | Yes |
| 54. Recognition of psychological (psychiatric) disorders from patient history information can be addressed in asynchronous online education. | 3.38 | 3.19 | 3.32 | 0.5 | Yes |
| 54a. NEW Recognition of psychological (psychiatric) disorders from patient history information can be addressed in interactive asynchronous online education. | | 3.33 | 3.42 | 0.5 | Yes |
| 55. Recognition of EEG patterns associated with head injury can be addressed in case-based learning modules online. | 3.63 | 3.57 | 3.47 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 56. Identification of the uses of EEG in surgery can be addressed in scenario-based learning modules online. | 3.54 | 3.62 | 3.63 | 0.5 | Yes |
| 56a. NEW Identification of the uses of EEG in surgery can be addressed in asynchronous online education. | | 3.38 | 3.58 | 0.5 | Yes |
| 57. Infection control procedures can be addressed in asynchronous online education. | 3.75 | 3.71 | 3.79 | 0 | Yes |
| 57a. NEW Practice of Infection Control procedures can be addressed with interactive on-line simulations. | | 3.38 | 3.68 | 0.25 | Yes |
| 58. National and regional health safety standards can be addressed in asynchronous online education. | 3.88 | 3.86 | 3.84 | 0 | Yes |
| 59. Universal precautions can be addressed in scenario-based learning modules online. | 3.83 | 3.86 | 3.89 | 0 | Yes |
| 60. Patient positioning for comfort and safety can be addressed in scenario-based learning modules online. | 3.46 | 3.48 | 3.42 | 0.5 | Yes |
| 61. Recognition of emergency situations can be addressed in scenario-based learning modules online. | 3.38 | 3.33 | 3.37 | 0.5 | Yes |
| 62. Appropriate responses to emergency situations can be addressed in scenario-based learning modules online. | 3.42 | 3.14 | 3.37 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 62a. NEW Appropriate responses to emergency situations can be addressed in team-based simulator training. | | 3.48 | 3.63 | 0.5 | Yes |
| 63. Compliance with sedation protocols can be addressed in asynchronous online education | 3.58 | 3.52 | 3.68 | 0.5 | Yes |
| 63a. NEW Compliance with sedation protocols can be addressed in scenario-based learning. | | 3.57 | 3.79 | 0 | Yes |
| 64. Disaster and emergency protocols can be addressed in scenario-based learning modules online. | 3.71 | 3.76 | 3.79 | 0 | Yes |
| 64a. NEW Disaster and emergency protocols can be addressed in team-based simulator training. | | 3.81 | 3.89 | 0 | Yes |
| 65. Fundamental NDT equipment maintenance can be addressed with problem-based learning online. | 3.38 | 3.24 | 3.47 | 0.5 | Yes |
| 65a. NEW Fundamental NDT equipment maintenance can be addressed with asynchronous online education. | | 3.52 | 3.63 | 0.5 | Yes |
| 66. Electrode application using the International 10-20 System of electrode placement can be addressed in asynchronous online education using problem-based learning addressing critical thinking, consequences of misplaced electrodes and using video demonstration, video assignments and video assessments. | 3.17 | 3.14 | 3.37 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 67. Placement of monitoring electrodes can be addressed in asynchronous online education with video demonstration. | 3.25 | 3.05 | 3.21 | 0.5 | Yes |
| 67a. NEW Placement of monitoring electrodes can be addressed in asynchronous online education with video demonstration, video assignments, video assessments, problem-based learning addressing critical thinking skills and addressing the results of incorrect placements. | | 3.43 | 3.53 | 0.5 | Yes |
| 68. Monitoring ECG/EKG can be addressed in asynchronous online education. | 3.63 | 3.57 | 3.63 | 0.5 | Yes |
| 68a. NEW Recognition of ECG/EKG abnormalities can be addressed in case-based learning modules online. | | 3.71 | 3.53 | 0.5 | Yes |
| 69. The importance of good electrode placement and consequences of poor placement can be addressed in asynchronous online education. | 3.54 | 3.62 | 3.58 | 0.5 | Yes |
| 69a. NEW The importance of good electrode placement and consequences of poor placement can be addressed in asynchronous online education and enhanced with simulations. | | 3.86 | 3.74 | 0.25 | Yes |
| 70. Advantages and disadvantages of different types of electrodes application methods can be addressed in asynchronous online education. | 3.58 | 3.62 | 3.89 | 0 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 71. International 10-20 Measurement techniques can be assessed using video assignments or assessments. | 3.21 | 3.1 | 3.42 | 0.5 | Yes |
| 71a. NEW International 10-20 Measurement techniques can be assessed using interactive simulation and problem-based learning directed at critical thinking skills. | | 3.24 | 3.47 | 0.5 | Yes |
| 72. Electrode application techniques can be assessed using video assignments or assessments. | 3.13 | 2.95 | 3.05 | 0.25 | Yes |
| 73. Preparation of electrode sites for electrode application can be addressed in asynchronous online education with video demonstration. | 3.17 | 3.24 | 3.42 | 0.5 | Yes |
| 74. Importance of low and balanced impedances can be addressed in asynchronous online education. | 3.67 | 3.67 | 3.68 | 0.5 | Yes |
| 75. Importance of stable electrode placement for lengthy EEG recordings can be addressed in asynchronous online education. | 3.71 | 3.71 | 3.79 | 0 | Yes |
| 76. Appropriate modifications of the 10-20 System to expand recording or make accommodations for skull defects or bandaging can be addressed in asynchronous online education. | 3.46 | 3.33 | 3.47 | 0.5 | Yes |
| 77. Different techniques of electrode application can be addressed in asynchronous online education with video demonstration. | 3.58 | 3.57 | 3.58 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 78. National or International standards in performance of EEG can be addressed in asynchronous online education. | 3.71 | 3.86 | 3.74 | 0.25 | Yes |
| 79. Montage use can be addressed in asynchronous online education with illustrations. | 3.46 | 3.38 | 3.47 | 0.5 | Yes |
| 79a. NEW Montage use can be addressed in problem-based learning modules online. | | 3.67 | 3.58 | 0.5 | Yes |
| 80. Appropriate instrument calibration can be addressed in asynchronous online education. | 3.46 | 3.57 | 3.63 | 0.5 | Yes |
| 81. The importance of EEG recording length in acquisition of sleep can be addressed in asynchronous online education. | 3.75 | 3.81 | 3.79 | 0 | Yes |
| 82. The use of activation procedures can be addressed in asynchronous online education. | 3.67 | 3.62 | 3.74 | 0.25 | Yes |
| 83. The importance of annotations on the EEG recording can be addressed in asynchronous online education. | 3.79 | 3.86 | 3.79 | 0 | Yes |
| 83a. NEW Including appropriate annotations on the EEG recording can be addressed in scenario-based learning modules online. | | 3.81 | 3.74 | 0.25 | Yes |
| 84. A common list of annotations to be programmed into the digital EEG instrument can be addressed in asynchronous online education. | 3.79 | 3.86 | 3.79 | 0 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 85. Design of an EEG recording strategy can be addressed in case-based learning modules online. | 3.5 | 3.67 | 3.47 | 0.5 | Yes |
| 86. Recording procedures for suspected electrocerebral inactivity (ECI) formerly called electrocerebral silence (ECS) can be addressed in asynchronous online education. | 3.5 | 3.43 | 3.37 | 0.5 | Yes |
| 87. Recording procedures for suspected electrocerebral inactivity (ECI) formerly called electrocerebral silence (ECS) can be enhanced in case-based learning modules online. | 3.67 | 3.71 | 3.63 | 0.5 | Yes |
| 88. Electrode removal procedures can be addressed in asynchronous online education containing results of correct and incorrect practices. | 3.5 | 3.62 | 3.53 | 0.5 | Yes |
| 88a. NEW Electrode removal procedures can be assessed in video assignments. | | 3.52 | 3.47 | 0.5 | Yes |
| 89. Appropriate attention to Medical Safety Data Sheets (MSDS) can be addressed in asynchronous online education. | 3.83 | 3.9 | 3.89 | 0 | Yes |
| 90. Occupational Safety and Health Administration (OSHA) regulations can be addressed in asynchronous online education. | 3.88 | 3.9 | 3.89 | 0 | Yes |
| 90a. NEW Occupational Safety and Health Administration (OSHA) regulations training can be enhanced with scenarios. | | 3.67 | 3.84 | 0 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 91. Compliance with the Health Insurance Portability and Accountability Act (HIPAA) can be addressed in asynchronous online education. | 3.67 | 3.76 | 3.89 | 0 | Yes |
| 91a. NEW Compliance with the Health Insurance Portability and Accountability Act (HIPAA) can be addressed with scenario-based learning modules online. | | 3.9 | 3.84 | 0 | Yes |
| 92. Processing EEG data can be addressed in asynchronous online education. | 3.54 | 3.52 | 3.58 | 0.5 | Yes |
| 93. Managing EEG data can be addressed in asynchronous online education. | 3.67 | 3.57 | 3.68 | 0.5 | Yes |
| 94. Application of spike-detection software can be addressed in asynchronous online education with illustrations of data and video demonstration. | 3.63 | 3.52 | 3.58 | 0.5 | Yes |
| 94a. NEW Application of spike-detection software can be assessed using case-based scenarios. | | 3.67 | 3.42 | 0.5 | Yes |
| 95. Customization of recording strategy to address needs of patients can be addressed in case-based learning modules online. | 3.46 | 3.43 | 3.42 | 0.5 | Yes |
| 96. Appropriate observation of patients during the EEG recording can be addressed in case-based learning modules online. | 3.46 | 3.24 | 3.21 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 96a. NEW Appropriate observation of patients during the EEG recording can be addressed in simulator training. | | 3.52 | 3.47 | 0.5 | Yes |
| 97. Application of polarity convention to localize EEG activity can be addressed with problem-based learning online. | 3.54 | 3.43 | 3.58 | 0.5 | Yes |
| 98. Recognition of developmental patterns in EEG data can be addressed in asynchronous online education rich in illustrations of EEG data samples. | 3.54 | 3.43 | 3.42 | 0.5 | Yes |
| 99. Recognition of developmental patterns in EEG data can be enhanced using case-based learning modules online. | 3.54 | 3.48 | 3.47 | 0.5 | Yes |
| 100. Patterns requiring immediate attention of the interpreting neurologist can be addressed in case-based learning modules online. | 3.33 | 3.24 | 3.37 | 0.5 | Yes |
| 101. Recognition of changes in the patient's state can be addressed in asynchronous online education rich in illustrations of EEG data samples. | 3.25 | 3.33 | 3.21 | 0.5 | Yes |
| 102. Recognition of life-threatening conditions can be addressed in case-based learning modules online. | 3.25 | 3.05 | 3.05 | 0 | Yes |
| 102a. NEW Recognition of life-threatening conditions can be addressed in case-based learning modules rich with examples and video demonstrations. | | 3.33 | 3.32 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 103/104. (Duplicate) Artifact recognition, monitoring or elimination techniques can be enhanced using case-based learning modules online. | 3.46 | 3.48 | 3.53 | 0.5 | Yes |
| 105. Recognition of ECG/EKG rhythm abnormalities can be addressed in asynchronous online education rich in illustrations and samples. | 3.63 | 3.57 | 3.53 | 0.5 | Yes |
| 106. Recognition of electrodes of questionable integrity needing reapplication or replacement can be addressed in asynchronous online education rich in illustrations and samples. | 3.38 | 3.33 | 3.53 | 0.5 | Yes |
| 107. Troubleshooting for sources of 60 or 50 Hz noise in the EEG data can be addressed in asynchronous online education rich in illustrations of EEG data with before and after samples. | 3.29 | 3.19 | 3.42 | 0.5 | Yes |
| 107b. Troubleshooting for sources of 60 or 50 Hz noise in the EEG data can be addressed with problem-based learning modules online. | | 3.38 | 3.32 | 0.5 | Yes |
| 108. Troubleshooting for sources of 60 or 50 Hz noise in the EEG data can be enhanced using scenario-based online learning modules. | 3.33 | 3.48 | 3.37 | 0.5 | Yes |
| 109. Appropriate submission of EEG recording data can be addressed in asynchronous online education. | 3.63 | 3.52 | 3.84 | 0 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 110. Appropriate patient assessment before and during the EEG recording can be addressed in asynchronous online education, rich with examples and illustrations. | 3.13 | 2.71 | 3 | 0 | Yes |
| 111. Appropriate patient assessment before and during the EEG recording can be enhanced using case-based learning modules online. | 3.29 | 3.19 | 3.26 | 0.5 | Yes |
| 111a. NEW Appropriate patient assessment before and during the EEG recording can be enhanced using simulation-based learning modules online. | | 3.43 | 3.21 | 0.5 | Yes |
| 112. Recognition of patients needing special assistance can be addressed in asynchronous online education. | 3.25 | 2.81 | 3.11 | 0.25 | Yes |
| 112a. NEW Recognition of patients needing special assistance can be addressed in problem-based learning modules online. | | 3.43 | 3.37 | 0.5 | Yes |
| 113. Appropriately responding to patients needing special assistance addressed using scenario-based learning modules online. | 3.29 | 3.14 | 3.26 | 0 | Yes |
| 114. Recognition of clinical or behavioral events of significance can be addressed in asynchronous online education. | 3.0 | 2.62 | 2.95 | 0.5 | Yes |
| 114a. NEW Recognition of clinical or behavioral events of significance can be addressed in problem-based learning modules online. | | 3.33 | 3.26 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 114b. NEW Recognition of clinical or behavioral events of significance can be enhanced by scenario based online education. | | 3.52 | 3.32 | 0.5 | Yes |
| 115. Appropriate responses to clinical or behavioral events of significance can be addressed using case-based learning modules online. | 3.17 | 3.1 | 3.26 | 0.25 | Yes |
| 116. Evaluation of the patient's level of cooperation and correlation with appropriate method of electrode application can be addressed in asynchronous online education. | 2.96 | 2.61 | 3.11 | 0.5 | Yes |
| 117. Coordination of patient's ability to cooperate with activation procedures can be addressed in asynchronous online education. | 2.83 | 2.48 | <u>2.74</u> | 0.25 | Yes |
| 117a. NEW Coordination of patient's ability to cooperate with activation procedures can be addressed using case-based learning modules online. | | 2.9 | <u>2.95</u> | 0.25 | Yes |
| 118. Contraindications for activation procedures can be addressed in asynchronous online education. | 3.63 | 3.52 | 3.74 | 0.5 | Yes |
| 119. The identification of artifacts can be addressed in asynchronous online education using multiple examples of problems and the resulting artifacts. | 3.5 | 3.43 | 3.53 | 0.5 | Yes |
| 120. Monitoring procedures for artifacts that cannot be eliminated can be addressed in scenario-based learning modules online. | 3.33 | 3.43 | 3.58 | 0.25 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 121. Recognition of other diagnostic procedures such as neuroimaging can be addressed in asynchronous online education. | 3.58 | 3.43 | 3.74 | 0 | Yes |
| 121a. NEW Recognition of other diagnostic procedures such as neuroimaging can be addressed in interactive asynchronous online education. | | 3.48 | 3.79 | 0 | Yes |
| 122. The responsibility of healthcare professionals to continually maintain and improve professional knowledge can be addressed in asynchronous online education. | 3.75 | 3.76 | 3.89 | 0 | Yes |
| 123. Professional accountability as established through standards and ethics (according to national or international standards) can be addressed in asynchronous online education. | 3.58 | 3.67 | 3.84 | 0 | Yes |
| 124. Professional accountability as established through standards and ethics (according to national or international standards) can be enhanced using scenario-based learning modules online. | 3.67 | 3.81 | 3.84 | 0 | Yes |
| 125. Observation of international, national, state, provincial and other applicable regulations or legislation can be addressed in asynchronous online education. | 3.79 | 3.81 | 3.84 | 0 | Yes |
| 126. Infection control practices according to national or international standards can be addressed in asynchronous online education. | 3.67 | 3.57 | 3.79 | 0 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 127. Observation of electrical safety standards and regulations can be addressed in asynchronous online education. | 3.58 | 3.57 | 3.84 | 0.5 | Yes |
| 128. Observation of appropriate seizure precautions can be addressed in asynchronous online education with video demonstrations. | 3.63 | 3.43 | 3.63 | 0.5 | Yes |
| 129. Seizure First Aid can be addressed in asynchronous online education with video demonstration. | 3.38 | 3.33 | 3.63 | 0 | Yes |
| 130. Recognition of a patient's right to refuse testing can be addressed in asynchronous online education. | 3.75 | 3.86 | 3.89 | 0.5 | Yes |
| 131. Training for emergency or disaster situations can be addressed in asynchronous online education with video demonstrations and is usually specialized to the facility and required for employment, so usually provided in the workplace. | 3.58 | 3.52 | 3.58 | 0 | Yes |
| 131a. NEW Training for emergency or disaster situations can be addressed in site-specific EEG facilities. | | 3.67 | 3.79 | 0 | Yes |
| 132. Cardiopulmonary Resuscitation is generally an outsourced training provided by employers to healthcare professionals either onsite or nearby and involves the demonstration and use of simulation mannequin and some aspects can be introduced and reviewed online. | 3.71 | 3.76 | 3.79 | 0.5 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 133. Situational awareness of ancillary equipment around the patient can be addressed in asynchronous online education. | 3.38 | 3.19 | 3.37 | 0.25 | Yes |
| 134. Regulation of the flow of oxygen for patients needing oxygen while an EEG study is performed can be addressed in scenario-based learning modules online. | 3.04 | 3.19 | 3.11 | 0.5 | Yes |
| 135. Providing a safe environment for the patient during EEG recording can be addressed in scenario-based learning modules online. | 3.33 | 3.57 | 3.63 | 0.5 | Yes |
| 136. Providing a comfortable environment for the patient during EEG recording can be addressed in scenario-based learning modules online. | 3.42 | 3.52 | 3.53 | 0.5 | Yes |
| 137. Transferring patients safely into or out of a gurney, wheelchair, bed or walker can be addressed in asynchronous online education with video demonstration. | 2.88 | 2.71 | 2.63 | 0.5 | Yes |
| 137a. NEW Transferring patients safely into or out of a gurney, wheelchair, bed or walker can be addressed in asynchronous online education with video demonstration and enhanced with additional hands-on training. |  | 3.29 | 3.26 | 0.5 | Yes |
| 138. The need for informed consent documentation can be addressed in asynchronous online education. | 3.83 | 3.86 | 3.89 | 0 | Yes |

| Delphi statement | R1 Mean | R 2 Mean | R3 Mean | IQD | Consensus |
|---|---|---|---|---|---|
| 139. Education regarding removal of electrodes and cleaning the patient's scalp can be addressed with asynchronous online modules, video demonstration and video assessment. | | 3.67 | 3.68 | 0.5 | Yes |

*Note.* Mean ratings under 3 are underlined. Delphi statements were developed using a combination of U.S. (ABRET, n.d.; CoA-NDT, 2012), Australian (ANTA, 2016), Canadian (CAET, 2011), and U.K. (ANS, 2014) competencies in the instrument.

The research questions examined the informed judgements and potential consensus of an expert panel of neurodiagnostic professionals, neurodiagnostic educators, educational technology experts, and educational technology educators about the use of educational technology in clinical skills training for neurodiagnostic technology students. Such students could obtain experience at the end of didactic training in a working residency. The goal was to find the opinions and potential consensus of experts about the use of educational technology to address NDT clinical skills training. Increased use of educational technology could provide schools of NDT a means to expand enrollments and graduates.

Consensus was established to be less than or equal to an IQD of 1. Consensus does exist among expert panelists in NDT and educational technology about the use of educational technology to address NDT competencies for performing EEG. All competencies were successfully paired with an educational technology and rated on the positive end of the scale (2.95 - 4). All but one competency paired with an educational technology with a rating of 2.95 remained below 3 in the final round. The panelists reached consensus on every statement in the competency list with an IQD of less than or equal to 0.5.

## Summary

The expert panelists rated a list of NDT competencies for EEG that were paired by the researcher with educational technology methods. The resulting data is listed in Table 2. During the course of three rounds, the panelists added 59 new statements. Positive consensus was established with ratings above 3 in all competencies except coordinating patient’s ability to perform activation procedures which was rated 2.95. Chapter Four described the results of the study. Chapter Five describes the study findings, limitations, implications, and recommendations for future use of the findings.

# Chapter 5: Discussion, Conclusions, and Recommendations

I conducted this Delphi study to explore the use of educational technology in neurodiagnostic technology clinical skills training for electroencephalography. Competencies from four countries were combined with ABRET's practice analysis to form a list of competencies for NDT technologists performing EEG. Creative use of educational technology may help reduce NDT schools' reliance on hospitals and clinics serving as clinical training sites. If EEG clinical skills can be taught with the use of educational technology, students may graduate into residencies where they could acquire needed experience before taking credentialing exams.

The expert panel rated educational technology methods effective in addressing the final list of 197 statements pairing competencies and educational technology methods. The use of educational technology to address clinical skills may decrease the restrictions imposed on NDT schools by the clinical site shortage. Graduates of NDT training programs using creative methods to effectively address EEG competencies could be placed in supervised residencies in hospitals or clinics. The number of clinical sites, therefore, would no longer govern the number of students in programs or limit the number of graduates. Consensus among expert panelists, representing both NDT and educational technology, indicated by this study, support the use of educational technology in NDT clinical skills training.

## Interpretation of Findings

The ratings of the expert panelists are in alignment with the conceptual framework of the study, a tenet of which is that experiential learning through a cognitive constructivist epistemology can be used to address clinical skill education in NDT. The first step in the study was to combine the competencies established for electroencephalographic technologists, by five professional organizations, in four countries. These competencies represent a task analysis of the cognitive and behavioral skills needed to perform basic EEG studies. Through educational technology, learners can engage in experiential learning using simulation and problem-, story-, scenario-, or case-based online modules (Cutrer et al., 2013; NLN, 2014; Shellenbarger & Robb, 2015). Cognitive constructivism recognizes knowledge as the internalization of a perception of reality that is constantly under revision or reevaluation (Schrader, 2015). According to cognitive constructivists, reality is known through cognition, built upon past experiences, and continually expanded through every new experience analyzed internally by the learner (Schrader, 2015).

I completed the initial pairing of educational technology methods. The initial pairings were open to revision by the panel of experts in the form of suggested new statements. The Delphi process allowed evolution of the statements pairing competencies and methods. Consensus developed during the study. The result was agreement that experiential learning through a cognitive constructivist lens can be applied to neurodiagnostic clinical skills using educational technology.

The findings of this study are aligned with the outcomes of other studies contained in the literature review in Chapter 2. Neurodiagnostic technology is not alone in the national and global shortage of hospitals or clinics willing to be clinical sites for students. According to the study by the National Council of Nursing Boards (Hayden et al., 2014), the shortage of clinical sites was limiting admission and graduates in the field of nursing. After turning away tens of thousands of qualified applicants in 2014 due to clinical site shortages, AACN studied the use of simulation to replace up to 50% of nursing clinical skills training (Hayden et al., 2014). The results of the study showed no compromise in learning outcomes and provided a variety of patient simulations including uncommon and severe illness simulations (Hayden et al., 2014). The simulation learning environment was found to be less stressful and allowed students to make mistakes without risk to patients (Hayden et al., 2014). The Hayden et al. (2014) empirical study resulted in no significant difference in clinical competency or National Council Licensure Examination pass rates.

Evidence of the effectiveness of educational technology comes from the U.S. Department of Education (2010) meta-analysis of evidence-based practices in online learning. The goal of the literature review was to evaluate the effectiveness of online learning compared to face-to-face instruction. Researchers examined 45 studies of K-12, medical, military, professional continuing education, and higher education. Based on the meta-analysis results, the researchers concluded that student outcomes were modestly better in online learning than in face-to-face classes and face-to-face classes benefitted from adding online elements for blended (hybrid) learning (U.S. Department of Education, 2010).

Kang et al. (2015) compared a control group of students who were given traditional lecture-based instruction with a second group experiencing the same content enhanced with problem-based learning and a third group who were engaged in problem-based learning and simulation. Posttest results confirmed the advantage of problem-based learning and simulation (Kang et al., 2015). The ratings of the panelists in this study are in line with the results of studies examining the effectiveness of problem-based learning and simulation (Kang et al., 2015).

**Conceptual Framework**

The conceptual framework of this study was the exploration of educational technologies to create an experiential learning environment (Aubrey & Riley, 2016; Donmez & Cagiltay, 2016; Kolb, 1984; Quay, 2003). I used cognitive constructivist epistemology (Schrader, 2015) to guide the research. Building active learning through engaged experiences such as simulation and case-, scenario-, story-, or problem-based learning (Frederickson et al., 2013) could become tools for clinical skills instruction in NDT. Cummings and Connelly (2016) surveyed students after simulation training and found significant improvement in active learning, refinement of critical thinking, and increased confidence.

Experiential learning begins with an intellectualization of a situation by the student, brainstorming of strategies and reasoning to examine consequences of potential strategies, then implementation and testing the success of the strategies (Kalkbrenner & Horton-Parker, 2016). It can be done independently or collaboratively, in a simulated classroom environment; virtual environment; or through the use of learning based on scenarios, cases, stories, or problems (Kalkbrenner & Horton-Parker, 2016). It involves the use of realistic experiences, personal engagement, and cognitive processing that guide behavior and advance didactic learning into the realm of clinical practice (Dernova, 2015). An advantage of educational technology use in clinical reasoning skills is safety for patients, decreased stress for learners, and inclusion of experiences uncommon or rare to clinical rotations (Kalkbrenner & Horton-Parker, 2016).

Experiential learning theory is an instructional design model that creates a student-centered environment for learners to engage in a transformational experience (Aubrey & Riley, 2016; Kolb, 1984). Such experiences put knowledge to work in solving real-world problems or situations, either in a heuristic, team, or guided model (Donmez & Cagiltay, 2016). According to Kolb (1984), experiential learning begins at any point along a cycle of exposure to a concrete experience, observation and reflections, abstract conceptualization, and active experimentation. These experiences of doing, observing, reflecting, thinking, and trial become experiential learning opportunities (Kolb, 1984).

Cognitive constructivist epistemology has been extended through educational technology and various forms of media creating engaging experiences through interaction with technology and provide social learning opportunities via media and technology (Schrader, 2015). These experiences evolve the learner’s knowledge and perspective similar to real-world engagement (Schrader, 2015). The experience of lecture presentation, demonstration, interaction, communication, discussion, and sense of learning community are common elements of online learning (Schrader, 2015). When simulation and problem-, scenario-, case-, or story-based learned are added, critical thinking or reasoning skills may develop in a virtual space (Cutrer et al., 2013; NLN, 2014; Shellenbarger & Robb, 2015).

In this Delphi study, I asked an expert panel to rate the application of different educational technologies, some of which create experiential learning through cases, stories, scenarios, problems, or simulation, to address EEG competencies. The result is a positive projection about the effectiveness of these technologies to help bridge the gap from didactic knowledge to clinical practice. Experiential learning can be done through direct experience, but also through the stories, cases, and problems as told through an online course or experienced in a simulation. By dissecting the professional skills into single competency statements, it is easier to imagine how educational technology can be used to address each cognitive task, each clinical decision, each critical evaluation, and each problem-solving process.

## Limitations of the Study

This study had a narrow focus of one modality of neurodiagnostics. Panelists were selected to represent the field of NDT and the field of educational technology. The panelists projected their expertise and experience in the exploration of an alternative method of training neurodiagnostic technologists. This study is an exploration of alternative clinical skill training. It does not challenge traditional means of training or clinical site placements. Placing students in a clinical site is a proven method of gaining clinical training and experience. The shortage of clinical sites has limited the flow of adequate numbers of graduates to supply the increasing demand for qualified professionals. This study is focused on finding alternative pathways to training that would allow greater numbers of graduates.

Attrition is expected during a Delphi Study (Keeney et al, 2011). The target sample size was set at 30 to provide leeway for some attrition. The sample size at round one was 24, round two had 22 responding and round three had 19 responding. The number of Delphi expert panelists are generally between 15 and 20 (Hsu & Sanford, 2012) and rarely exceed 30 (Sekayi & Kennedy, 2017). After the expected attrition, the final number of participants was within the 15 to 20 range.

One issue that became apparent during the first round of the Delphi was the need for more complete explanations of some of the competencies for the educational technology experts. Between the first and second rounds the researcher provided some explanations of the terms; activation procedure; assessment of the patient state; EEG calibration; and electrical safety standards. Not all types of education were included in the study and the rating was for simple effectiveness of the methods listed. The ratings were not intended to compare the statements to any other type of educational approach. Clarification of the impetus and narrow focus of the study, to explore alternative educational pathways to achieving clinical skills other than the traditional clinical site rotations, was explained in an email following the second round.

There is evidence that similar professions have used simulation, problem-based, story-based, scenario-based and case-based learning to address clinical skills training (Frederickson et al., 2013; Hayden et al., 2014; Kalkbrenner & Horton-Parker, 2016). Prior to this study, these methods had not been explored in NDT as an alternative to clinical site placements. Clinical experience is an important part of training in any allied healthcare professionals, but the shortage of willing clinical sites is the reality facing all healthcare educators. This study is a first step of exploration. The next steps include development of a model and exploring educational technology use in other modalities of NDT.

## Recommendations

This study may be used as a guide to development of a model pathway to clinical skills using educational technology. The next step would be to develop a training model that integrates more educational technology to address clinical skills and follow didactic training with a residency for clinical experience. After laying a foundation of experiential learning through the use of educational technology, clinical experience could be supervised by a registered technologist or physician in a residency following didactic training. Cases, stories, scenarios, and problems that mimic realistic experiences can provide experiential learning to guide clinical practice (Dernova, 2015; Kalkbrenner & Horton-Parker, 2016). One advantage of structured experiential learning using educational technology is the ability to incorporate even rare cases and unusual circumstances that may not occur during a clinical rotation.

The Delphi study format should be used to address other modalities and specializations of neurodiagnostic technology. Such an examination of other competencies may result in a positive opinion of the use of educational technology. If not, the process will isolate those competencies that experts consider not well suited for educational technology.

This study is a first step in examining experiential learning through educational technology as applied to NDT. It adds to the existing literature supporting the effectiveness of educational technology to address clinical skills. Dissecting the larger concept of *clinical skills* into individual tasks, as done in cognitive task analysis (Tekkumru-Kisa et al., 2015) has been used to take a deep look at the requirements for each clinical competency. When examined individually, the competencies are specific and easier to evaluate.

**Recommendations for Practice**

The first step in putting the findings of this study into practice would be to develop experiential learning modules, using educational technology, and placing them into the NDT curricula of training programs. The process of integrating experiential cases, stories, scenarios, problems, and simulations that address or reinforce those clinical skills usually taught through experience in a clinical site would build a foundation of clinical reasoning skills. The advantage of creating experiential learning modules is the inclusion of a larger number and variety of cases, situations, and circumstances, even those rarely seen in the NDT lab. Creutzfeldt-Jakob disease (CJD) or spongiform encephalopathy in humans, is a rarely occurring, infectious, fatal disease (WHO, 1999). CJD patients have seizures as part of the disease process, so patients with CJD will likely have an EEG. The signature EEG pattern of CJD and precautions needed to avoid the spread of the disease, make recognition of the pattern essential, yet many technologists do not record an EEG on a patient with CJD during their career (Waterhouse, 2014). The use of experiential learning modules and educational technology make it possible for every student to have a virtual experience of a patient with CJD. From pattern recognition to the appropriate steps to insure precautions are taken, this experience does not have to wait years to be part of the memory and experience of the technologist. Through detailed cases, scenarios, stories, and problems, the student can experience the patient from presentation, symptoms, history, preparation, and testing followed by the recognition of the pattern and appropriate actions. The detailed story creates a mental model and the critical thinking decisions can be created using a branching scenario. The correct answers lead to correct pattern recognition. The incorrect answers result in failure but without health consequences to actual patients. The more vivid and realistic the experiential learning, the better the memory of the experience.

**Use of educational technology**. Educational technology is the study and practice of facilitating learning and improving performance by creating, using, and managing appropriate technological processes and resources (Association for Educational Communications and Technology, 2012). Educational technology can be used to create experiential learning at a distance by using real-life problems to be solved, authentic patient case studies, scenarios designed to present a challenge to be resolved, or a story that immerses the student into different perspectives (Dewey, 1933; Kalkbrenner & Horton-Parker, 2016; Kolb, 1984). Rather than presenting steps, facts, sequences, or objects for memorization, the student is engaged in an experience that generates a complex memory complete with sensory and emotional elements (Lavoie et al., 2016; Paliadelis et al., 2015; Shaw et al., 2017). Stories are used in the basic development and socialization of children and they remain an effective learning tool for adults (Bransford, Brown, & Cocking, 2000).

Case-based learning is a pedagogy that uses authentic medical case examples to train medical and allied health professionals by engaging the student in the details of the case (Fortun et al., 2017). Cases are designed from initial contact to diagnosis and treatment or from the presentation of the patient for testing to the conclusion of testing (Fortun et al., 2017). This method increases performance and motivation of students. It has been used in medicine for many years to promote critical thinking and clinical reasoning but is being incorporated into the curriculum earlier in healthcare professions to promote development of clinical reasoning skills (Fortun et al., 2017).

Problem-based learning [PBL] has its origins in medical training to build critical or clinical judgment through the student-centered practice of realistic problem-solving experiences (Wyles et al., 2013). Problem-based and case-based learning combined with a multidisciplinary approach is being used to develop interprofessional collaboration skills in allied healthcare professionals (Lin & Chin, 2013; Nasir, Goldie, Little, Banerjee, & Reeves, 2017). Problems from artifact identification in EEG to emergency situations can be developed into problem-based online learning. The introduction to the problem may include a detailed description, visual aids, interaction with other students and the instructor, video demonstrations, and branching scenarios that engage the student. The problems encountered in experiential online learning can mimic clinical experiences of all types and can be conducted in a virtual environment (Wyles et al., 2013).

Scenario-based learning places the learner into a specific set of circumstances calling for appropriate decisions to be made in a student-centered experiential learning environment. Scenarios can be experienced through reading, engagement, or interaction in an online environment or discussion in a virtual or traditional classroom (Barbera et al., 2017; Persson et al., 2014; Weston, 2015). A scenario for NDT students could include what to do if a patient has a seizure while in the NDT lab. A scenario could be built around the challenges associated with performing an EEG on a pediatric patient, a patient in Intensive Care Unit (ICU), a patient in the neonatal ICU, a psychiatric patient who is uncooperative, a two-year old who is hyperactive, or a patient being evaluated for possible electrocerebral silence.

Story-based learning is a pedagogical method using rich engaging stories of patients and families to engage students in an emotional, social, ethical, economic, and cultural experience that goes beyond the clinical case presentation by having participants examine situations from different perspectives. It is student-centered learning exposing learners to different perspectives in situations through reading, discussing, or adopting different perspectives within a detailed story. Story-based learning is engaging and can add situational awareness to instructional design (Lavoie et al., 2016; Shaw et al., 2017). Story-based learning can become transformative learning when the student is given the opportunity to examine a perspective other them his or her own perspective (Kroth & Cranton, 2014). According to Oatley (2018), the more rich and vivid the story, the more the student's brain is engaged and the more expansive are the roots of the memory activated by the story. Reading vivid stories produces a mental model which is like a simulation which can be used for instruction and learning (Oatley, 2018). Stories used in learning can convey empathy, morality, and experience.

The list of Delphi statements could be used as a guide to pairing methods with competencies. In the results of this study, a panel of experts rated educational technology methods that in their opinion would effectively address the graduate competencies for performing EEG. The results of the study guide educators in an effective approach. For instance, in Delphi statement 136 *Providing a comfortable environment for the patient during EEG recording can be addressed in scenario-based learning modules online,* development of the learning module would begin with listing different scenarios involving patient comfort. These would include infant and pediatric patients, patients with physical or mental handicaps, patients who might be physically ill at the time of testing, and elderly patients needing assistance moving or walking.

Solutions to making the patient comfortable would include a cheerful, nonthreatening décor for the lab, comfortable bed or recliner, lighting that can be dimmed, sheet and blanket for cover, assistance when needed, and close proximity of family or friend. Interactions with the patient should be cordial and polite. Children need time to get to know the technologist, minus the white lab coat, before the procedure begins. Everything done to the pediatric patient should first be done to the parent such as measuring, preparing the electrode site, and placing the electrode. Infants need their usual toys, blanket, bottle, and pacifier. Bed rails should be used to protect the patient. Interactions should be professional. Clinical reasoning can be engaged by providing examples of both correct and incorrect surroundings and behavior. Story-based learning can help them realize the perspective of the patient. Once a learning module has addressed the different types of patients and what makes them more or less comfortable, then a scenario can be introduced that requires the student to address the patient's comfort.

Branching scenario software such as Captivate or Articulate can create a simulation of running the EEG instrument with choices of different sensitivity or filter settings applied to short video clips of EEG data linked to the selected settings. The student is interactively learning by trying the different choices and seeing the impact on the EEG data. This can be reinforced with multiple samples and tested in the same manor. This is experiential learning though interacting with the online module in a similar fashion to interacting with the EEG instrument.

Pattern recognition is an important skill for EEG technologists and a large collection of samples is needed to give adequate exposure to all essential patterns. Student must be exposed to many samples to develop the skill of recognizing patterns. Testing should be with new data samples that clearly demonstrates the characteristics of the pattern, but the data should not be taken from practice modules. The data used in testing should be new to the student if the skill of pattern recognition is to be assessed. All essential information such as history, age, and state should be provided for pattern recognition but no information that would identify the patient should be included. Schools may wish to collaborate on large scale EEG sample databases, but EEG atlases can be used to expose students to multiple samples.

Video presentation can be used to present cases, scenarios, or problems, but video can also be used in assignments. Cell phones are readily available in developing countries and most cell phones have a video camera. The International 10-20 System of electrode application is a hands-on skill that can be demonstrated in short, step-by-step video clips and a corresponding video can be assigned to students to demonstrate each step of the skill. This process may take more time but is similar to standing near the student providing guidance. The instructor can provide feedback to the student by screen-capturing images from their video assignment. These images are then placed in PowerPoint or Keynote, allowing the instructor to circle misplaced marks, place arrows between marks illustrating asymmetries and highlighting incorrect methods or hand positions. Additionally, the instructor can type feedback on the slide. The slides are then exported as images for the student to review or a new video demonstration clip can be provided illustrating the correct method. Feedback should be provided in private, but the student can be asked if they are willing to share the feedback with other students. The students can engage in a discussion online about what they learned during the assignment, what errors they made, and what they found most difficult. Students can also share how they overcame the difficulty.

Using educational technology to address clinical skills requires research and development followed by ongoing instructor interactivity with the students. It also requires that online students receive personal feedback. Engagement is an essential element for successful use of educational technology. After the modules are developed, the capacity for expanding the number of students is limited only by instructor availability. Schools could expand enrollments and staff to address the workforce needs no longer restricted by the number of hospitals and clinics willing to take students into their NDT labs.

Standing behind the results of this study are other research and meta-analysis supporting the effectiveness of online delivery of education. The U.S. Department of Education has found in a meta-analysis that online education is modestly better than classroom education (U.S. Department of Education, 2010). A study by Kemp and Grieve (2014) found that online learning led to similar academic achievement when compared to classroom activities. The American Association of Colleges of Nursing has found no decrease in learning outcomes with 50% of clinical training done using simulation (Hayden et al., 2014). As online education is increasingly used and studied, the skeptics about the effectiveness of online education are diminishing. Studies show no significant difference in outcomes as reported in Thomas Russell’s book, *The No Significant Difference Phenomenon* (1999). Russell’s book summarizes 355 research reports, summaries, and papers describing no significant difference between outcomes of learning presented online or in a classroom.

The second step after implementing experiential learning modules would be to monitor students’ grades and student impressions of their experiences. As the nursing profession has monitored the effectiveness of using simulation in 50% of nursing clinical training, NDT student progress and graduate success should be tracked. Feedback from students is also essential. An advantage of online learning is its immediate and ongoing editability. If student scores are actively monitored, adjustments can be made to the experiential learning modules, quizzes, or exams immediately. Integrating new material always requires close observation, evaluation, and redesign after implementation. With this in mind and to add to the ease in updating content, keeping modules divided into small easily edited increments is advisable. Changes in standards, guidelines, procedures, and terminology would also require periodic updates to content.

Cases, stories, problems, and scenarios encountered in clinical practice can be developed as experiential learning models to give students the skills needed for clinical reasoning, problem-solving, and experience with different types of clinical situations. Instructional design with truly rich development of stories, cases, scenarios, or problems and interactive engagement can create experiential learning similar to clinical experiences. Experiential learning modules using realistic situations, stories, and cases have the advantage of not being limited by happenstance. Every important case, example, situation, disease, disorder, event, or problem can be developed into experiential learning modules. Course designers can add to the sample pages of neurodiagnostic data usually included in didactic learning, a detailed story complete with a pseudo-image or cartoon image of the patient to create a case or story. Technologists who have worked long in the field can collaborate on the development of modules describing interesting cases, unusual circumstances, and problems to solve.

Engaging as many of the student's senses as possible enhances experiential learning (Dernova, 2015; Dewey, 1933; Kolb, 1984; Kalkbrenner & Horton-Parker, 2016). In a branching scenario, tell the story of the patient, his or her family background, and interject the student into the scenario as the technologist. Create an interaction between the characters including choices made by the technologist and variable outcomes. Set as a goal to replicate real life experiences of patients and technologists that incorporates patient interaction; infection control; history-taking; recording strategy; evaluation of patient's state; contraindications; evaluation of patient's cooperation; artifact recognition; sleep staging; pattern recognition; storing of EEG data; lab and patient clean up. Interview staff or other NDT professionals for challenging stories from their experiences in the lab. Remember to deidentify and alter the story to protect patient privacy.

NDT schools may want to collaborate in the development of simulations using realistic case presentations, interjecting technical issues to be resolved, and special circumstances requiring clinical reasoning. However online learning development software becomes easier to use and more affordable with each iteration. Online simulation development tools help instructional designers turn learning into experiences. Because the developer of these experiences is the educator, the student experiences are not limited to what happens to occur in the lab during their rotation day. The experiences are only limited by the imagination and creativity of the developer. Educational technology allows every technologist to experience rare and unusual cases, a multitude of artifacts to identify, and situations in which to develop and apply clinical reasoning.

**What would success look like?** When a sufficient number of clinical experiences have been integrated into the training using educational technology, time in clinical rotations could be moved to a clinical residency. If clinical reasoning is well established in experiential online learning, time in a residency would provide needed experience and clinical confidence. Placement of residents who have completed didactic training including clinical skills training, training for patient safety, and comprehensive courses in neurodiagnostics would likely be easier than placing students. The shortage of qualified NDT professionals has perpetuated on-the-job training at hospitals and clinics. Hospitals and clinics are unable to find fully qualified technologists to fill job openings in EEG labs, long-term epilepsy monitoring units, twenty-four-hour continuous EEG monitoring in intensive care units and intraoperative neuromonitoring teams (ASET, 2014; Bureau of Labor and Statistics, 2016; CoA-NDT, 2018). Hospitals willing to host residents for a year of experience would be gaining trained but novice technologists who have completed didactic training enhanced with experiential learning through educational technology. During their residency, while they gain experience, they will also establish a working relationship with the facility hosting the residency. It would be an opportunity for the technologist and employer to assess if a longer-term employment arrangement would be a good option. If not, the technologist can look for long term employment after gaining valuable work experience during the residency.

When experiential learning is in place and clinical experience is moved to a residency at the end of training, enrollment of greater numbers of students would be possible in all existing schools. Schools with established clinical rotation sites may provide an alternative pathway to some students ending in a residency while still rotating some students in established clinical sites. Students in remote locations could complete their training online and then travel to work during their residency at an institution that can provide oversight by an ABRET registered technologist and physician. For many years, the lack of suitable clinical sites has left some states both in shortage of qualified NDT professionals, and unable to provide training for those wishing to enter the field because there are no clinical sites available. The cycle of no trained technologists resulting in no pathway to train technologists has left areas of the United States without the ability to provide neurodiagnostic care to citizens. If the nearest clinical site is hundreds of miles away, it is impractical to travel there for a few hours, several times a week. However, moving to a larger city for a residency at the end of training allows the student to return to their community after the residency and begin to provide neurodiagnostic services in an area where the services did not exist before. In this way, remote areas could begin to provide neurodiagnostic services and provide residencies for local trainees.

The goal of this research was not the elimination of training in clinical sites, but the exploration of how educational technology might provide a pathway to greater numbers of graduates to fill the growing need. This study focused on the skills for performing EEG studies, a basic foundation of training for neurodiagnostics but in no way inclusive of all aspects of NDT. Future studies may address nerve conduction studies, polysomnography, evoked potentials, long-term monitoring for epilepsy, continuous EEG monitoring for patients in intensive care units, and intraoperative neuromonitoring. If a training pathway can be established that places didactic training first, including experiential learning using educational technologies, followed by residencies or internships, the field would have no obstacles to enrollments and graduate numbers could increase. When the existing schools graduate more than a thousand students each year, the field would begin to sustain itself without the need of on-the-job training.

## Implications

The positive social change that could result from exploring an alternative pathway to obtaining NDT clinical skills is an expansion of enrollments and graduates from the existing schools of NDT in the United States and around the world. The acceptance of trying new ways of addressing clinical skills education is a variable that is hard to predict. More graduates would result in increased availability and higher quality neurodiagnostic care for patients. With greater numbers of graduates, schools of NDT would be less likely to be at risk of closure for financial reasons. The shortage of clinical sites is experienced throughout healthcare professions. Other professions such as nursing have begun to address the problem using educational technology, paving the way for other healthcare professions like NDT (NLN, 2014; Raehl et al., 2013; Romig et al., 2017; U.S. Department of Education, 2010; Wilkinson et al., 2015).

Another type of social change that may be triggered by this study is described by Sousanis in his book, *Unflattening* (2015). Sousanis describes this type of social change as the illumination of boundaries that narrow the perspective on possibilities. Sousanis writes of the common yet unconscious human state of acceptance that curtails exploration, confining thought to the limited dimension of the status quo. Unflattening, as defined by Sousanis, is transcending the status quo to discover new perspectives, fresh methods of cognition, dynamic wonder, and open space for possibilities. If this study begins a dialogue among NDT educators about the possibilities of new ways to achieve the common goals of increasing the qualified workforce in NDT, then it has been successful.

## Conclusion

This study created a structured dialogue between neurodiagnostic experts and educational technology experts to explore the use of technology in providing students with clinical skills training. The study began with a combined list of competencies from five sources in four countries. The combined list of competencies served as a cognitive, psychomotor, and affective skill task analysis for the performance of EEG recording. The dissection of professional skills into individual tasks served to simplify the concept of developing instruction to address each competency. The Delphi methodology minimized group dynamics and the impact of dominant personalities allowing each panelist to rate the effectiveness of each competency paired with educational technology method.

Consensus was achieved with a positive effectiveness rating in all competencies paired with educational technology methods. Only two of the paired competencies and methods were given a mean rating between 2.5 and 3. Ratings of 2.63 and 2.95 were given to competencies in moving patients from a gurney or wheelchair and evaluating patient cooperation with activation procedures, respectively. All other competencies matched with an educational technology method were rated between 3 and 4 on a scale of 1-4, with 4 being high. These results reflect positively on the establishment of an alternative pathway to clinical skill training for NDT professionals to include educational technology and clinical experience during a post-graduate residency. This alternative pathway could result in expanding enrollment, increasing graduates, and securing the future of NDT training programs.

The placement of NDT students in willing clinical sites has become so problematic that the United States is graduating fewer than 300, combined national total, from the existing schools each year (CoA-NDT, 2018). Efforts to enlist additional clinical sites have failed to increase the number of national graduates. Clinical skills training using experiential learning through educational technology would provide a pathway to graduating greater numbers of NDT professionals to better supply the increasing demand of the workforce.

This study does not challenge the effectiveness of using clinical site rotations in training NDT students. It does challenge the effectiveness of traditional training methods to supply the United States with an adequate number of qualified NDT professionals. The outcome of this study shows a positive opinion among experts in NDT and educational technology that the competencies for performing clinical EEG can be addressed using educational technology. If clinical skills can be addressed during didactic learning, and clinical experience gained in a residency following didactic learning, schools could admit and graduate greater numbers of qualified NDT professionals. More qualified NDT professionals would provide greater availability of neurodiagnostic care to patients, more employment opportunities and greater financial security for existing schools of NDT. Neurodiagnostic technology is a fascinating profession and a job opportunity that holds exciting potential for professional growth. Neurodiagnostic care is an essential part of quality healthcare for citizens in the United States and around the world.

# References

Adler, M., & Ziglio, E. (1996). *Gazing into the oracle*. London, U.K.: Kingsley.

Alconero-Camarero, A. R., Gualdron-Romero, A., Sarabia-Cobo, C. M., & Martinez-Arce, A. (2016). Clinical simulation as a learning tool in undergraduate nursing: Validation of a questionnaire. *Nurse Education Today, 39*, 128-134. doi:10.1016/j.nedt.2016.01.027

Al-Dahir, S., Bryant, K., Kennedy, K. B., & Robinson, D. (2014). Online virtual-patient cases versus traditional problem-based learning in advanced pharmacy practice experiences. *American Journal of Pharmaceutical Education, 78*(4), 1-7. doi:10.5688/aipe78476

American Association of Sleep Technologists [AAST] (n.d.) Sleep technologist cope of practice. Retrieved January 17, 2019, from https://www.aastweb.org/sleep-technologist

American Board of Registration of Electroencephalographic and Evoked Potential Technology. (n.d.). ABRET practice analysis. Retrieved from http://abret.org/candidates/credentials/practice-analysis/

American Job Center. (2017). Summary report for: 29-2099-01: Neurodiagnostic technologists. Retrieved January 17, 2019, from http://www.onetonline.org/link/summary/29-2099.01

Arthur, C., Levett-Jones, R., & Kable, A. (2013). Quality indicators for the design and implementation of simulation experiences: A Delphi study. *Nurse Education Today, 33,* 1357-1361. doi:10.1016/j.nedt2012.07.012

ASET– The Neurodiagnostic Society. (n.d.). *Clinical site database information*. Retrieved January 17, 2019, from http://www.aset.org/i4a/pages/index.cfm?pageid=3796

ASET – The Neurodiagnostic Society. (2011). Scope of practice for neurodiagnostic technology. Retrieved January 17, 2019, from https://www.aset.org/i4a/pages/index.cfm?pageid=4182

ASET – The Neurodiagnostic Society. (2015). The 2015 ASET salary survey. Retrieved May 1, 2016, from http://www.aset.org

ASET – The Neurodiagnostic Society. (2016). Editorial: Building a qualified neurodiagnostic technology workforce [Editorial]. *The Neurodiagnostic Journal, 56,* 131-138. doi:10.1080/21646821.1202721

ASET – The Neurodiagnostic Society. (2018). List of accredited NDT schools. Retrieved from https://www.aset.org/i4a/pages/index.cfm?pageid=3584

Association for Educational Communications & Technology. (2012). *AECT Standards, 2012 version*. Retrieved from https://www.aect.org/docs/AECTstandards2012.pdf

Association of Neurophysiological Scientists. (2014). Competencies. Retrieved from https://www.ansuk.org

Association of Neurophysiological Technologists. (2016). Competencies. Retrieved from https://www.anta.org.au

Aubrey, K., & Riley, A. (2016). *Understanding & using educational theories*. Los Angeles, CA: Sage.

Baker, S., Painter, E., Morgan, B., Kaus, A. L., Peterson, E. J., Allen, C., ... & Jensen, G. M. (2017). Systematic clinical reasoning in physical therapy (SCRIPT): Tool for the purposeful practice of clinical reasoning in orthopedic manual physical therapy. *Physical Therapy, 97*(1), 61-70. doi:10.2522/ptj.20150482

Bandura, A. (1977). *Social learning theory.* New York: NY: General Learning Press.

Barbera, E., Garcia, I., & Fuetes-Alpiste, M. (2017). A co-design process microanalysis: Stages and facilitators of an inquiry-based and technology enhanced learning scenario. *International Review of Research in Open and Distributed Learning, 18*(6), 104-126. Retrieved from http://www.irrodl.org/index.php/irrodl/index

Benedict, N., Smithburger, P., Donihi, A. C., Empey, P., Kobulinsky, L., Seybert, A., … & Meyer, S. (2017). Blended simulation progress testing for assessment of practice readiness. *American Journal of Pharmaceutical Education, 81*(1), 1-13. doi:10.5688/ajpe81114

Benner, P. (1982). From novice to expert. *American Journal of Nursing, 82*(3), 402-407. Retrieved from http://www.jstor.org/stable/3462928

Benner, P., Stuphen, M., Leonard, V., & Day, L. (2010). *Educating nurses: A call for radical transformation.* San Francisco, CA: Jossey-Bass, The Carnegie Foundation.

Birko, S., Dove, E., & Ozdemir, V. (2015). Evaluation of nine consensus indices in Delphi foresight research and their dependency on Delphi survey characteristics: A simulation study and debate on Delphi design and interpretation. *PLOS One, 10*(8), 1-14. doi:10.1371/journal.pone.0135162

Boddy, C. R. (2016). Sample size for qualitative research. *Qualitative Market Research: An International Journal, 19*(4), 426-432. doi:10.1177/1049732315617444

Bonner, A. (2016). Editorial: Building a qualified neurodiagnostic workforce. The Neurodiagnostic Journal, 58(3), 131-138. doi:10.1080/21646821.2018.1519333

Bolesta, S., & Chmil, J. V. (2014). Interprofessional education among student health professionals using human patient simulation. *American Journal of Pharmaceutical Education, 78*(5), 94. doi:10.5688/ajpe78594

Bransford, J. D., Brown, A. L., & Cocking, R. R., [Eds]. (2000). *How People Learn Brain, mind, experience and school*. National Research Council. Washington, D. C.: National Academic Press. doi:10.17226/6160

Bureau of Labor and Statistics (2017). 29-2099 Health technologists and technicians, all other. Retrieved from http://www.bls.gov/soc/2010/soc292099.htm

Burns, J., & Anderson, R. (1993). Attentional inertia and recognition memory in adult television viewing. *Communication Research, 20*(6). doi:10.1177/009365093020006002

CAAHEP (2015). Commission on accreditation of allied health education programs. Retrieved from https://www.caahep.org

Canadian Association of Electroneurophysiology Technologists [CAET] (2011). *Entry-to-Practice Competencies.* Retrieved from https://www.caet.org

Clark, R. C. (2013). *Scenario-based e-learning: Evidence-based guidelines for online workforce training.* San Francisco, CA: Pfeiffer.

CoA-NDT (2008). Commission on Accreditation of Allied Health Education Programs: Standards and guidelines for accreditation of educational programs in neurodiagnostic technology. Retrieved from: http://coa-ndt.org/wp-content/uploads/2012/04/NDT-Standards-Final-2008.pdf

CoA-NDT (2012). Committee on Accreditation for Education in Neurodiagnostic Technology. *Graduate competencies for neurodiagnostic technology*. Retrieved from http://coa-ndt.org

CoA-NDT (2018). Committee on Accreditation for Education in Neurodiagnostic Technology. Graduate statistics. Retrieved from http://coa-ndt.org

Cummings, C. L., & Connelly, L. K. (2016). Can nursing students' confidence levels increase with repeated simulation activities? *Nurse Education Today, 36*, 419-421. doi:10.1016/j.nedt.2015.11.004

Cutrer, W. B., Sullivan, W. M., & Fleming, A. E. (2013). Educational strategies for improving clinical reasoning. *Current Problems in Pediatric and Adolescent Healthcare, 43*(9), 248-257. doi:10.1016/j.cppeds.2013.07.005

Czeropski, S. (2015). Changing behaviors and intrinsic motivation through scenario-based learning: A case study. *Performance Improvement, 51*(3), 16-24. doi:10.1002/pfi.21465

Dalkey, N. C. (1969). *The Delphi method: An experimental study of group opinion*. Santa Monica, CA: Rand. Retrieved from https://www.rand.org/pubs/research_memoranda/RM5888.html

de Oliveira, S. N., do Prado, M. L., Kempfer, S. S., Martini, J. G., Caravaca-Morera, J. A., & Bernardi, M. C. (2015). Experiential learning in nursing consultation education via clinical simulation with actors: Action research. *Nurse Education Today, 35*, e50-e54. doi:10.1016/j.nedt.2014.12.016

Dernova, M. (2015). Experiential learning theory as one of the foundations of adult learning practice worldwide. *Comparative Professional Pedagogy, 5,* 52-57. doi:10.1515/rpp-2015-0040

Dewey, J. (1933). *How we think: A restatement of the relation of reflective thinking to the educative process*. Boston, MA: D. C. Health.

Doll, M. A., Wear, D., & Whitaker, M. (2006). Teaching: A return to wonder. In M.A. Doll, D. Wear, & M. Whitaker (Eds.). *Triple take on curricular worlds.* (pp. 164-169). New York, NY: State University Press.

Donmez, M., & Cagiltay, K. (2016). *A review and categorization of instructional design models. Proceedings E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education*. Washington DC: Association for the Advancement of Computing in Education (AACE). Retrieved from https://www.learntechlib.org/p/173964/

Doshi, N. (2016). "How we integrate pathology in the preclinical medical curriculum using Bond Virtual Hospital app." Presentation at the Fourth Asia-Pacific Global Summit & Expo on Healthcare. Brisbane, Australia, July 18-20, 2016.

Dreyfus, S. E. (2004). The five-stage model of adult skill acquisition. *Bulletin of Science, Technology & Society, 24*(3), 177-181. doi:10.1177/0270467604264992

Dy-Boarman, E. A., Diehl, B., Mobley-Burkstein, W., Bottenberg, M. M., Bryant, G. A., & Sauer, H. (2017). Comparison of faculty and student self-assessment scores of aseptic technique skills and the impact of video review on self-awareness for second year pharmacy students. *Currents in Pharmacy Teaching and Learning, 10,* 1-5. doi:10.1016/j.cptl.2017.10.021

Ellaway, R. H., Poulton, T., & Jivram, T. (2015). Decision PBL: A 4-year retrospective case study of the use of virtual patients in problem-based learning. *Medical Teacher, 37*(10), 926-934. doi:10.3109/0142159X.2014.970627

Falk, K., Falk, H., & Jakobsson, E. (2016). When practice precedes theory – A mixed methods evaluation of students' learning experiences in an undergraduate study program in nursing. *Nurse Education in Practice, 16*(1), 14-19. doi: 10.1016/j.nepr.2015.05.010

Farahat, E., Rice, G., Daher, N., Heine, N., Schneider, L., & Connell, B. (2015). Objective structured clinical examination [OSCE] improves perceived readiness for clinical placement in nutritional and dietetic students. *Journal of Allied Health, 44*(4), 208-214. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/26661699

Fletcher, A., & Marchildon, G. (2014). Using the Delphi method for qualitative, participatory action research in health leadership, 1-15. *The International Journal of Qualitative Methods.* doi:10.1177/160940691401300101

Fortun, J., Morales, A. C., & Tempest, H. G. (2017). Introduction and evaluation of case-based learning in the first foundational course of an undergraduate medical curriculum. *Journal of Biological Education, 51*(3), 295-304. doi: 10.1080/00219266.2016.1217909

Frederickson, R., McMahan, S., & Dunlap, K. (2013). Problem-based learning theory. In Irby, B. J., Brown, G., Lara-Alecio, R. 7 Jackson, S. (Eds.), *The handbook of educational theories.* (pp. 211-218). Charlotte, NC: Information Age Publishing.

Fu, W. (2015). Development of an innovative tool to assess physical therapists' clinical reasoning competency. *Journal of Physical Therapy Education, 29*(4), 14-26. doi: 10.1097/00001416-201529040-00004

Furth, H. G. (1968). Piaget's theory of knowledge: The nature of representation and interiorization. *Psychological Review, 75*(2), 143-154. doi:10.1037/h0025515

Furze, J., Black, L., Hoffman, J., Barr, J. B., Cochran, T. M., & Jenson, G. M. (2015).

Exploration of students' clinical reasoning development in professional physical therapy education. *Journal of Physical Therapy Education, 29*(3), 22-33. doi: 10.1097/00001416-201529030-00005

Galloway, S. (2009). Simulation techniques to bridge the gap between novice and competent professionals. *Online Journal of Issues in Nursing, 14*(2), 7-17. doi: 10.3912/OJIN.Vol14No02Man03

Gavgani, V. Z., Hazrati, H., & Ghojazadeh, M. (2015). The efficacy of digital case scenario versus paper case scenario on clinical reasoning in problem-based learning: A systematic review and meta-analysis. *Research and Development in Medical Education, 4*(1), 17-22. doi:10.15171/rdme.2015.003

Gaze, P. A. (2015). Using technology to meet the challenges of medical education. *American Clinical and Climatological Association, 126*, 260-270. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4530721/

Gee, B. M., Thompson, K., Strickland, J., & Miller, L. J. (2017). The development of a measurement tool evaluating knowledge relating to sensory processing among graduate occupational therapy students: A process description. *Occupational Therapy International, 2007*, 1-7. doi:10.1155/2017/6713012

Gilliland, S. (2017). Physical therapist students' development of diagnostic reasoning: A longitudinal study. *Journal of Physical Therapy Education, 31*(1), 31-48. Retrieved from https://journals.lww.com/jopte/Abstract/2017/31010/Physical_Therapist_Students__Development_of.7.aspx

Goulding, H., Kay, R., & Li, J. (2016). Assessing the impact of a virtual lab in healthcare education. *E-Learn 2016 Proceedings*. Washington, DC. 923-928. Retrieved from https://www.researchgate.net/profile/Robin_Kay/publication/311485602_Assessing_the_Impact_of_a_Virtual_Lab_In_Health_Care_Education/links/584ec8c808aecb6bd8d010ed/Assessing-the-Impact-of-a-Virtual-Lab-In-Health-Care-Education.pdf

Habibi, A., Sarafrazi, A., & Izadyar, S. (2014). Delphi technique theoretical framework in qualitative research. *The International Journal of Engineering and Science, 3*(4), 8-13. Retrieved from https://pdfs.semanticscholar.org/6716/d422e438025a9531da82368f1ebdbe620daf.pdf.

Harman, T., Bertrand, B., Greer, A., Pettus, J. J., Wall-Bassett, E., & Babatude, O. T. (2015). Case-based learning facilitates critical thinking in undergraduate nutrition education: Students describe the big picture. *Journal of the Academy of Nutrition and Dietetics, 115*(3), 378-389. doi:10.1016/j.jand.2014.09.003

Hawkins-Walsh, E., Berg, M., Docherty, S., Lindeke, L., Gaylord, N., & Osborne, K. (2011). A national survey of the primary and acute care pediatric nurse practitioner educational preparation. *Journal of Pediatric Healthcare, 25*(1), 5-15. doi:10.1016/j.pedhc.2010.06.005

Hayden, J. K., Smiley, R. A., Alexander, M., Kardong-Edgren, S., & Jeffries, P. R. (2014). The NCSBN national simulation study: A longitudinal randomized, controlled study, replacing clinical hours with simulation in prelicensure nursing education. *Journal of Nursing Regulation, 5*(2), S3-S40. doi:10.1016/S2155-8256(15)30062-4

Hsu, C. C., & Sanford, B. A. (2012). Delphi Technique. *Encyclopedia of Research Design.* Thousand Oaks, CA: SAGE. doi:10.4018/978-1-4666-0074-4.ch011

INACSL (2016). International Nursing Association for Clinical Simulation and Learning. *Standards of best practice*. Retrieved from https://www.inacsl.org/i4a/pages/index.cfm?pageID=3407

Iverson, K., & Colky, D. (2004). Scenario-based e-learning design. *Performance Improvement, 43*(1), 16-22. doi:10.1002/pfi.4140430105

Iqbal, S., & Pipon-Young, L. (2009). The Delphi method: Methodological issues arising from a study examining factors influencing the publication or non-publication of mental health nursing research. *The Psychologist, 22*, 598-601. Retrieved from https://thepsychologist.bps.org.uk/volume-22/edition-7/delphi-method

Jeffries, P. (2008). Getting in S.T.E.P. with simulations: Simulations take educator preparation. *Nursing Education Perspectives, 29*(2), 70-74. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/18459620

Joint Commission of Pharmacy Practitioners (2014). Patient care process. Retrieved from https://jcpp.net/?s=Patient+Care+Process

Kalkbrenner, M. T., & Horton-Parker, R. J. (2016). Applying John Dewey's theory of education to infuse experiential learning in an introduction to human services course. *Journal of Human Services, Fall,* 65-68. Retrieved from https://digitalcommons.odu.edu/cgi/viewcontent.cgi?article=1032&context=chs_pubs

Kang, K. A., Kim, S., Kim, S. J., Oh, J., & Lee, M. (2015). Comparison of knowledge, confidence in skill performance (CSP) and satisfaction in problem-based learning

(PBL) and simulation with PBL educational modalities in caring for children with bronchiolitis. *Nurse Education Today, 35*(2), 315-321. doi:10.1016/j.nedt.2014.10.006

Keeney, S., Hasson, F. & McKenna, H. (2011). *The Delphi technique in nursing and healthcare.* West Sussex, UK: John Wiley & Sons. doi:10.1002/9781444392029

Keller, J. M. (2008). First principles of motivation to learn and e-learning*. Distance Education, 29*(2), 175-185. doi:10.1080/01587910802154970

Keller, J. M. (2010). *Motivational design for learning and performance.* New York, NY; Springer. doi:10.1007/978-1-4419-1259-3_8

Kemp, N., & Grieve, R. (2014). Face-to-face or face-to-screen? Undergraduates' opinions and test performance in classroom vs. online learning. *Frontiers in Psychology, 5*, 1278. Doi:10:3389/fpsyg.2014.01278

Keskitalo, T., & Ruokamo, H. (2015). A pedagogical model for simulation-based learning in healthcare. *Media, Technology and Life-Long Learning, 11*(2), 1-11. Retrieved from https://journals.hioa.no/index.php/seminar/article/view/2352/2181

Keskitalo, T., & Ruokamo, H. (2016). *Students' emotional in simulation-based medical education. Proceedings of E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education*. Washington, DC: U.S. Association for the Advancement of Computing in Education (AACE), 719-725. Retrieved from https://www.learntechlib.org/p/173999/

Keskitalo, T., Ruokamo, H., Vaisanen, O., & Gaba, D. (2013). Healthcare facilitators' and students' conceptions of teaching and learning: An international case study. *International Journal of Educational Research, 62,* 175-186. doi:

10.1016/j.ijer.2013.09.001

King, A. (1993). From sage on the stage to guide on the side. *College Teaching, 41*(1), 30-35. Retrieved from http://www.jstor.org/stable/27558571

King, S., Liu, L., Stroulia, E., & Nikolaidis, I. (2013). Simulations in the workplace: Integrating technology into healthcare aides' workflow. *International Journal of Advanced Corporate Learning, 6*(2), 28-31. doi:10.3991/ijac.v6i2.2982

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development.* Englewood Cliffs, N.J.: Prentice-Hall, Inc.

Kroth, M., & Cranton, P. (2014). Stories of transformative learning. *International issues in adult education 14*. Boston: Sense Publishers.

Kwant, K., Custers, E. J. F. M., Jongen-Hermus, J., & Kluijtmans, M. (2015). Preparation by mandatory learning of practical skills: A quasi-experimental comparison of skill examination results. *BMC Medical Education, 15*(1), 1-8. doi: 10.1186/s12909-015-0376-4

Landeen, J., Carr, D., Culver, K., Martin, L., Matthew-Maich, N., Noesgaard, C., & Beny-Gadsby, L. (2016). The impact of curricular changes on BSCN students' clinical learning outcomes. *Nurse Education in Practice, 21,* 51-58. doi: 10.1016/j.nepr.2016.09.010

Lavoie, P., Cossette, S., & Pepin, J. (2016). Testing nursing students' clinical judgment in a patient deterioration simulation scenario: Development of a situation awareness instrument. *Nurse Education Today, 38,* 61-67. doi:10.1016/j.nedt.2015.12.015

Leigh, G., Stueben, F., Harrington, D., & Hetherman, S. (2016). Making the case for simulation-based assessments to overcome the challenges in evaluating clinical competency. *International Journal of Nursing Education and Scholarship, 13*(1), 5-13. doi:10.1515/ijnes-2015-0048

Li, A. M. L. (2016). Simulation-based clinical skill training to promote effective clinical learning with simulation evaluation rubrics in nursing education. *International Journal of Information and Education Technology, 6*(3), 237-242. doi:10.7763/IJIET.2016V6.692

Lin, Y. C., & Chin, C. C. (2013). The impact of an interprofessional problem-based learning curriculum of clinical ethics on medical and nursing students' attitudes and ability of interprofessional collaboration: A pilot study. *Kaohsiung Journal of Medical Sciences, 29*(9), 505-511. doi:10.1016/j.kms.2013.05.006

Long, K. A. (2003). Institute of Medicine report health professions education: A bridge to quality. *Policy, Politics, & Nursing Practice 4*(4), 259-262. Sage Publications. doi:10.1177/1527154403258304

Lunney, M. (2010). Use of critical thinking in the diagnostic process. *International Journal of Nursing Terminologies and Classifications, 21*(2), 82-88. doi: 10.1111/j.1744-618X.2010.01150.x

MacLean, S., Kelly, M., Geddes, F., & Della, P. (2017). Use of simulated patients to develop communication skills in nursing education: An integrative review. *Nurse Education Today, 48*, 90-98. doi:10.1016/j.nedt.2016.09.018

McCusker, K., & Gunaydin, S. (2015). Research using qualitative, quantitative or mixed methods and choice based on the research. *Perfusion, 30*(7), 537-542. doi:10:1177/0267659114559116

McDougall, E. M. (2015). Simulation in education for healthcare professionals. *British*

*Columbia Medical Journal*, *57*(10), 444-448. http:www.bcmj.org

McIntosh, C., Patterson, J., & Miller, S. (2018). First year midwifery students' experience with self-recorded and assessed video of selected midwifery practice skills at Otago Polytechnic in New Zealand. *Nurse Education in Practice, 28,* 54-59. doi:10.1016/j.nepr.2017.09.016

McLean, M., Brazil, V., & Johnson, P. (2014). How we "breathed life" into problem-based learning cases using a mobile application. *Medical Teacher, 36,* 849-852. doi:10.3109/0142159X.2014.886771

McPherson, C., & MacDonald, C. (2017). Blending simulation-based learning and interpretive pedagogy for undergraduate leadership competency development. *Journal of Nursing Education, 56*(1), 49-54. doi:10.3928/01484834-20161219-10

Michels, M., Evans, D., & Blok, G. A. (2012). What is a clinical skill? Searching for order in the chaos through a modified Delphi process. *Medical Teacher, 34*(8), e573-581. doi:10.3109/0142159X.2012.669218

Mohide, E. A., & Drummond-Young, M. (2001). Developing problems for use in problem-based learning. (pp. 165-192). In E. Rideout, E. (Ed.), *Transforming nursing education through problem-based learning.* USA: Jones and Bartlett Publishers. doi:10.1016/S0260-6917(02)00070-9

Motola, I., Devine, L. A., Chung, H. S., Sullivan, J. E., & Issengerg, B. (2013). Simulation in healthcare education: A best evidence practical guide. AMEE Guide N. 82. *Medical Teacher, 35*(10), e1511-e1530. doi:10.1016/S0260-6917(02)00070-9

Murdock, N. L., Bottorff, J. L., & McCullough, D. (2013). Simulation education approaches to enhance collaborative healthcare: A best practices review. *International Journal of Nursing Education Scholarship, 10*(1), 1-8. doi: 10.1515/ijnes-2013-0027

Nasir, J., Goldie, J., Little, A., Banerjee, D., & Reeves, S. (2017). Case-based interprofessional learning for undergraduate healthcare professionals in the clinical setting. Journal of Interprofessional Care, 31(1), 125-128. doi: 10.1080/1356

National Aeronautics and Space Administration (2012). Mars pathfinder egg drop challenge. Retrieved from https://www.nasa.gov/offices/education/programs/national/summer/education_resources/engineering_grades7-9/E_egg-drop.html

NCES (2011). National Center for Education Statistics. Demongraphics. Retrieved from https://nces.ed.gov/fastfacts/display.asp?id=28

NLN (2014). National League of Nursing. *National League of Nursing response to NCSBN simulation study*. Retrieved from http://www.nln.org/docs/default-source/about/nln-vision-series-(position-statements)/ncsbnstudyresponsefinal.pdf?sfvrsn=4

Nevin, M., Neill, F., & Mulkerrins, J. (2014). Preparing the nursing student for internship in pre-registration nursing program: Developing a problem-based approach with the use of high-fidelity simulation equipment. *Nurse Education in Practice, 14*(2), 154-159. doi:10.1016/j.nepr.2013.07.008

Oatley, K. (2018). *Our minds, our selves: A brief history of psychology*. New Jersey: Princeton University Press.

O'Brien, J. E., Hagler, D., & Thompson, M. S. (2015). Designing simulation scenarios to support performance assessment validity. *The Journal of Continuing Education in Nursing, 46*(11), 492-498. doi:10.3928/00220124-20151020-01

Odyssey of the Mind (2017). Retrieved from https://www.odysseyofthemind.com/p/

Paliadelis, P. S., Stupans, I., Parker, V., Piper, D., Gillan, P., Lea, J., … Fagan, A. (2015). The development and evaluation of online stories to enhance clinical learning experiences across health professional in rural Australia. *Collegian, 22*(4), 397-403. doi:10.1016/j.colegn.2014.08.003

OSET (2017). Organization of Societies of Electrophysiological Technology. Retrieved from http://oset.org

Pappas, C. (2015). The quintessential of the situated cognition theory and its application to eLearning course design. *eLearning Industry, 608 Shares, Jun 7, 2015*. Retrieved from http://elearningindustry.com/situated-cognition-theory-and-cognitive-apprenticeship-model.com

Paul, S. A. (2014). Assessment of critical thinking: A Delphi Study. *Nurse Education Today, 34*(11), 1357-1360. doi:10.1016/j.nedt.2014.03.008

Persson, J., Dalholm, E. H., Wallergard, M., & Johansson, G. (2014). Evaluating interactive computer-based scenarios designed for learning medical technology. *Nurse Education in Practice, 14*(6), 579-585. doi:10.1016/j.nepr.2014.05.004

Qualtrics (2018). Sophisticated research made simple. Retrieved from https://www.qualtrics.com/research-core/

Qualtrics (2017). *Qualtrics: Security Ver.5.01. Information Security: A brief overview of privacy, compliance, and operational policies and procedures*. [white paper].

Qualtrics.

Quay, J. (2003). Experience and participation: Relating theories of learning. *The Journal of Experiential Education, 26*(2), 105-116. doi:10.1177/105382590302600208

Raehl, C. L., Baldwin, J. N., Carter, R. A., Crabtree, B. L., Yanchick, V. A., & Maine, L. L. (2013). Game changers in education and healthcare: Report of the 2012-13 Argus commission. *American Journal of Pharmaceutical Education, 77*(10), 1-10. doi: 10.5688/ajpe7710S18

Raurell-Torredá, M., Olivet-Pujol, J., Romero-Collado, A., Malagon-Àguilera, M. C., Patinõ-Masó, J., & Baltasar-Bagué, A. (2014). Case-based learning and simulation: Useful tools to enhance nurses' education? Nonrandomized controlled trial. *Journal of Nursing Scholarship, 47*(1), 34-42. doi:10.1111/jnu.12113

Reime, M. H., Johnsgaard, T., Kvam, F. I., Aarflot, M., Breivik, M., Engeberg, J. M., & Brattebo, G. (2016). Simulated settings; powerful arenas for learning patient safety practices and facilitating transference to clinical practice. A mixed-method study. *Nurse Education in Practice, 21,* 75-82. doi:10.1016/j.nepr.2016.10.003

Ridder, H. (2017). The theory contribution of case study research design. *Business Research, 10*, 281-305. doi:10.1007/s40685

Rivkin, A. (2016). Thinking clinically from the beginning: Early introduction of the pharmacists' patient care process. *American Journal of Pharmaceutical Education, 80*(10), 1-10. doi:10.5688/ajpe8010164

Rodger, S., Turpin, M., Copley, J., Coleman, A., Chien, C., Caine, A., & Brown, T. (2014). Student practice evaluation form revised edition online comment bank: Development and reliability analysis. *Australian Occupational Therapy Journal,* *61*(4), 241-248. doi:10.1111/1440-1630.12115

Romero-Hall, E. (2016). A framework for designing instructional computer-based simulations: Research-based strategies for appropriate design. *Proceedings of EdMedia: World Conference on Educational Media and Technology Association for the Advancement of Computing in Education (AACE), Vancouver, BC, Canada,* 1604-1611. Retrieved from http://www.learntechlib.org/search/?q=A+framework+for+designing+instructional+computer-based+simulations

Romig, B. D., Tucker, A. W., Hewitt, A. M., & Maillet, J. O. (2017). The future of clinical education: Opportunities and challenges from allied health deans' perspective. *Journal of Allied Health, 46*(1), 43-55. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/28255596

Rosen, K. R. (2008). The history of medical simulation. *Journal of Critical Care, 23*(2), 157-166. doi:10.1016/j.jcrc.2007.12.004

Rowe, M., Frantz, J., & Bozalek, V. (2012). The role of blended learning in the clinical education of healthcare students: A systematic review. *Medical Teacher, 34*(4), e216-221. doi:10.3109/0142159X.2012.642831

Russell, R. L. (1999). *The no significant difference phenomen as reported in 355 research papers, summaries and papers.* North Carolina State University: IDEC. Retrieved from http://www.nosignificantdifference.org

Rutberg, S., & Bouikidis, C. D. (2018). Exploring the evidence: Quantitative and qualitative research: Focusing on the fundamentals: A simplistic differentiation between qualitative and quantitative research. *Nephrology Nursing Journal,* *45*(2), 209-212. Retrieved from https://library.annanurse.org/anna/search/0/query?tag=method%20design

Rutherford-Hemming, T., Nye, C., & Coram, C. (2016). Using simulation for clinical practice hours in nurse practitioner education in the U.S.: A systematic review. *Nurse Education Today, 37,* 128-135. doi:10.1016/j.nedt.2015.11.006

Scheffer, B. K., & Rubenfeld, M. G. (2000). A consensus statement on critical thinking. *Journal of Nursing Education, 39*(8), 352-359. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/11103973

Schott, V., & Cook, S. (2016). An examination of the effect of simulation training on knowledge transfer and performance improvement for newly graduated nurses. *Proceedings of E-Learn 2016 World Conference of E-Learning in Corporate, Government, Healthcare and Higher Education. Association for the Advancement of Computing in Education (AACE).* Washington DC, U.S., 119-124. Retrieved from https://www.learntechlib.org/noaccess/173928/

Schrader, D. E. (2015). Constructivism and learning in the age of social media: Changing minds and learning communities. *New Directions in Teaching and Learning*, *144,* 23-35. doi:10.1002/tl.20160

Sekayi, D., & Kennedy, A. (2017). Qualitative Delphi method: A four round process with a worked example. *The Qualitative Report, 22*(10), 2755-2763. Retrieved from https://nsuworks.nova.edu/tqr/vol22/iss10/15

Shanahan, M. (2016). Utilizing activity theory as a framework to evaluate the implementation of a virtual simulation education tool: *Proceedings of EdMedia 2016-World Conference on Educational Media and technology*. *Association for* *the Advancement of Computing in Education (AACE).* Vancouver, BC, Canada, 769-779. Retrieved from https://www.learntechlib.org/p/173037/.

Shaw, A., Lind, C., & Ewashen, C. (2017). Harlequin-inspired story-based learning: An educational innovation for pediatric nursing communication. *Journal of Nursing Education, 56*(5), 300-303. doi:10.3928/01484834-20170421-09

Shellenbarger, T., & Robb, M. (2015). Technology-based strategies for promoting clinical reasoning skills in nursing education*. Nurse Educator, 40*(2), 79-82. doi:10.1097/NNE.0000000000000111

Society for Simulation in Healthcare [SSH] (2017). *Challenges of implementing healthcare simulations in community colleges.* White papers. Retrieved from http://www.ssih.org

Sousanis, N. (2015). *Unflattening.* Cambridge, MA: Harvard University Press. http://doi.org/10.5334/cg.ax

Stathakarou, N., Zary, N., & Kononowicz, A. A. (2014). Virtual patients in massive open online courses: Design implications and integration strategies. *Proceedings of e-Health – For Continuity of Care*. Open Access Creative Commons: European Federation for Medical Informatics and IOS Press, 493-497. doi:10.3233/978-1-61499-432-9-793

Stewart-Lord, A. (2016). From education to research: A journey of utilizing virtual training. *Journal of Radiotherapy in Practice, 15,* 85-90. doi:10.1017/S1460396916000030

Tekkumru-Kisa, M., Stein, M. K., & Schunn, C. (2015). A framework for analyzing cognitive demand and content-practices integration: Task analysis guide in science. *Journal of Research in Science Teaching, 52*(5), 659-685. doi:10.1002/tea.21208

Thomas, C. M., Sievers, L. D., Kellgren, M., Manning, S. J., Rojas, D. E., & Gamblian, V. C. (2015). Developing a theory-based simulation educator resource. *Nursing Education Perspectives, Sept-Oct,* 340-342. doi:10.5480/15-1673

Tjiam, I. M., Schout, B. M. A., Hendrikx, J. M., Scherpbier, J. J. M., Witjes, J. A., & Van Merrienboer, J. G. (2012). Designing simulator-based training: An approach integrating cognitive task analysis and four-component instructional design. Medical *Teacher, 34*(10), 698-707. doi:10.3109/0142159X.2012.687480

Tolsgaard, M. G., Madsen, M. E., Ringsted, C., Oxlund, B. S., Sorensen, J. L., Ottesen, B., & Tabor, A. (2015). The effect of dyad versus individual simulation-based ultrasound training on skills transfer. *Medical Education, 49*(3), 286-295. doi: 10.1111/medu.12624

Trobec, I., & Starcic, A. J. (2015). Developing nursing ethical competencies online versus in the traditional classroom. *Nursing Ethics, 22*(3), 352-366. doi:10.1177/0969733014533241

Trommelen, R. D., Karpinski, A., & Chauvin, S. (2017). Impact of case-based learning and reflection on clinical reasoning and reflection abilities in physical therapist students. *Journal of Physical Therapy Education, 31*(1), 21-30. Retrieved from http://search.proquest.com/openview/0eddc8f7e687e6d9dbb52291985fa95a/1?pq-origsite=gscholar&cbl=26719

U.S. Department of Education (2010). Evaluation of evidence-based practices in online learning: A meta-analysis and review of online learning studies. *U.S. Department* *of Education,* 1-66. Retrieved from https://www2.ed.gov/rschstat/eval/tech/evidence-based-practices/finalreport.pdf

Veenstra, G. L., Ahaus, K., Welker, G. A., Heineman, E., van der Laan, M. J., & Muntinghe, L. H. (2017). Rethinking clinical governance: healthcare professionals' views; a Delphi study. *BMJ Open, 7:*e012591, 1-7. doi:10.1136/bmjopen-2016-012591

Von der Gracht, H. A. (2012). Consensus measurement in Delphi studies: Review and implications for future quality assurance. *Technology Forecasting & Social Change, 70,* 1525-1536. doi:10.1016/j.techfore.2012.04.013

Vygotsky, L. S. (1981). The genesis of higher mental functions. In J. Wertsch, (Ed.), *The concept of activity in Soviet psychology*. (pp. 144-188). Armonk, NY: Sharpe.

Wainwright, S. F., & Gwyer, J. (2017). (How) can we understand the development of clinical reasoning? *Journal of Physical Therapy Education, 31*(1). doi: 10.1097/00001416-201731010-00003

Warren, S. J., Lee, J., & Najmi, A. (2014). The impact of technology and theory on instructional design since 2000. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop, (Eds.), *Handbook of research on educational communications and technology,* (4th ed., pp. 89-100). New York: Springer. doi:10.1007/978-1-4614-3185-5

Waterhouse, E. (2014). Generalized Encephalopathy. In Ebersole, J. S., Husain, A. M., & Nordli, D. R. (Eds.). *Current Practice of Clinical Electroencephalography 4th Ed.*, 213-237. Philadelphia: Wolters Kluwer. doi: 10.1002/1n1.410090229

Weise, J., Fisher, K. R., & Trollor, J. (2016). Utility of a modified online Delphi method to define workforce competencies: Lessons from intellectual disability mental health core competencies project. *Journal of Policy and Practice in Intellectual Disabilities, 13*(1), 15-22. doi:10.1111/jppi.12142

Wells, M. E., & Vaughn, B. V. (2013). Sleep technologist's educational needs assessment: A survey of polysomnographic, electroneurodiagnostic technology and respiratory therapy education program directors. *American Academy of Sleep Medicine, 9*(10), 1081-1086. doi:10.5664/jcsm.3088

Weston, A. (2015). From guide on the side to impresario with a scenario. *College Teaching, 63,* I99-104. doi:10.1080/87567555.2015.1014993

Wilkinson, D. M., Smallidge, D., Boyd, L. D., & Giblin, L. (2015). Students' perceptions of teaching methods that bridge theory to practice in dental hygiene education. *The Journal of Dental Hygiene, 89*(5), 330-337. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/26519497

Woda, A. A., Gruenke, T., Alt-Gehrman, P., & Hansen, J. (2016). Nursing student perceptions regarding simulation experience sequencing. *Journal of Nursing Education, 55*(9), 528-532. doi:10.3928/01484834-20160816-07

World Health Organization (2013). Global health workforce shortage to reach 2.9 million in coming decades. *World Health Organization*. Retrieved from http://www.who.int/mediacentre/news/releases/2013/health-workforce-shortage/en/

World Health Organization (1999). WHO infection control guidelines for transmissible spongiform encephalopathies. Report of a WHO consultation, Geneva, Switzerland. *World Health Organization.* Retrieved from:

http://www.who.int/csr/resources/publications/bse/WHO_CDS_CSR_APH_2000_3/en/

Wyles, E., McLeod, H., & Goodfellow, G. (2013). A novel approach to bridge the gap between didactic and clinical education. *Optometric Education*, *39*(1)*,* 12-19. Retrieved from https://journal.opted.org/articles/Volume_39_Number_1_Article1.pdf

Yeung, C., McMillan, C., Saun, T. J., Sun, K., D'hondt, V., Martou, G., … & Binhammer, P. (2017). Developing cognitive task analysis-based educational videos for basic surgical skills in plastic surgery. *Journal of Surgical Education, 74*(5), 889-897. doi:10.1016/j.jsurg.2017.01.008

Yoo, M. S., & Park, J. H. (2014). Effect of case-based learning on the development of graduate nurses' problem-solving ability. *Nurse Education Today, 34*(1), 47-51. doi: 10.1016/j.nedt.2013.02.014

Zori, S. (2016). Teaching critical thinking using reflective journaling in a nursing fellowship program. *The Journal of Continuing Education in Nursing, 47*(7), 321-329. doi:10.3928/00220124-20160616-09

## Appendix A: Combined Competencies

I developed the Delphi statements using a combination of U.S. (ABRET, n.d.; CoA-NDT, 2012), Australian (ANTA, 2016), Canadian (CAET, 2011), and U.K. (ANS, 2014) competencies.

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| **Clinical Skill Domain 1: Patient Preparation, Interaction, Communication & Teamwork** | **IA1** Verify Identity of patient | | **3.2 Patient Assessment and Intervention**<br>**3.2 a** Verify patient's identity<br>**5.1 Fundamental Clinical Procedures**<br>**a.** Verify procedure has been ordered<br>**b.** Ensure procedure requisition contains required information; address inconsistencies | **2. Preparation**<br>**a.** Identify the process for patients to attend and leave the clinic.<br>**b.** Prepare consumables appropriately<br>**c.** Prepare the environment according to WH&S regulations.<br>**d.** Register correct data for patient.<br>**e.** Obtain appropriate patient consent<br>**f.** Identify sufficient recording space for recording<br>**3. Patient Care**<br>**a.** Identify correct patient, correct procedure | **Core Criteria: 1.1** Ensure that all patient information pertinent to the investigation is available and checked for validity in accordance with recommended procedures. 1.2 Evaluate patient information and plan the investigation.<br>1.3<br>Review the location for the investigation and the needs of the patient.<br>**Specific Criteria: Portable EEG**<br>1.4<br>Make arrangements where necessary for the transport of equipment and accessories outside the dedicated laboratory<br>Core Criteria:<br>3.1 Confirm the patient's identity matches that on the referral documents.<br>3.2 Accurately | **1.Preparation**<br>**a.** Verify patient identify<br>**b.** Verify the procedure is ordered<br>**c.** Examine information on the order for required elements and address inconsistencies<br>**d.** Prepare consumables appropriately<br>**e.** Prepare environment according to regulations<br>**f.** Obtain appropriate patient consent<br>**g.** Identify sufficient recording space for recording<br>**h**. When needed transport patient or instrument to the bedside |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | enter/identify the patient's information on the recording machine. | |
| | **IB1** Establish rapport with patient & family, achieving relaxation & cooperation of patient **IB2** Explains testing procedure & activation procedures **IB3** Explains electrode application method | **T-2** Explain the testing procedure to patient/caregivers in a manner consistent with their ability to understand in order to establish rapport and elicit cooperation and; **K-15** Techniques for establishing rapport | **3.3 Communication and Education** **3.3 a** Identify self-technologist) and explain the professional role (of NDT) **3.3 b** Facilitate patient's understanding by encouraging and responding to questions and concerns **3.3 c** Respond to patient's family/representative within the parameters of patient confidentiality **3.3 d** Refer patient concerns to other healthcare providers as appropriate | **3. Patient Care** **a.** Introduce self and others present | **Specific Criteria: Child over 5 years** 1.5 Make the recording area suitable for children. 1.6 Ensure any specific arrangements are made where appropriate. 3.3 Establish effective communication with the patient/carers and explain the test in a manner liable to ensure their co-operation. | **2. Establish patient rapport** **a.** Introduce self and others present to patient and family and explain professional role **b.** Put patient at ease **c.** Achieve patient cooperation **d.** Encourage patient to respond to questions **e.** Make needed and appropriate accommodations for infants and children |
| | **IB4** Interacts on a level appropriate to age & mental capacity | **K-14** Age-specific criteria **K-16** Cognitive limitations | | **3. Patient Care** **a.** Demonstrate appropriate patient interaction 1. according to age, clinical state and cultural differences 2. provide sufficient pre-test information 3. gain sufficient pre-test information 4. explain the procedure including answering questions | **Specific Criteria: Child over 5 years** 3.14 Encourage parents, siblings and care-givers to participate. 3.15 Fully inform parents, relatives and caregiver of the nature and purpose of the investigation. 3.16 Adopt a suitable approach to the child to optimize co-operation. | **3. Patient Care: Explain Procedures** **a.** Explain procedure including activation procedures and electrode application **b.** Respond to patient's family/representative within the parameters of patient confidentiality **c.** Refer patient concerns to other healthcare providers as appropriate **4. Patient** |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | | **Instructions**<br>**a.** Interact on an appropriate level to patient's age, culture and cognitive ability<br>**b.** Provide sufficient pre-test information<br>**c.** Gain sufficient pre-test information<br>**d.** Explain the procedure including answering questions<br>e. Inform patient on procedure to obtain test results |
| | | | **1.2 Teamwork**<br>**a.** Interact effectively as a member for a multidisciplinary healthcare team<br>**b.** Distinguish between the scopes of practice of healthcare team members<br>**c.** Demonstrate respect for a diversity of opinions and values<br>**d.** Manage personal workload to contribute to team productivity<br>**e.** Communicate effectively both orally and in writing<br>**f.** Utilize medical terminology in professional communication<br>**g.** Apply basic problem-solving and conflict resolution techniques<br>**h.** Provide constructive feedback to colleagues | | **3.4 Knowledge Specification Neurophysiological Principles Required for Planning the EEG**<br>The need to liaise with parents/guardian to ensure maximum co-operation of the child.<br>The need to liaise with nursing staff, where appropriate, to ensure that the patient is not compromised.<br>The level and type of support which the physiologist can give to a patient who is suffering a seizure or disturbed state.<br>Environment is appropriately prepared and all necessary consumables and equipment available in | **5. Teamwork and inter-professional collaboration:**<br>**a.** Interact effectively as a member for a multidisciplinary healthcare team<br>**b.** Distinguish between the scopes of practice of healthcare team members<br>**c.** Demonstrate respect for a diversity of opinions and values<br>**d.** Manage personal workload to contribute to team productivity<br>**e.** Communicate effectively both orally and in writing<br>**f.** Utilize medical terminology in professional communication<br>**g.** Apply basic |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | a dedicated or non-dedicated environment. Procedures and responsibilities for notification of follow-up arrangements. Policies and arrangements for escorting and/or transporting patients. | problem-solving and conflict resolution techniques<br>**h.** Provide constructive feedback to collegues |
| **Clinical Skill Domain 2: History Taking** | **IC5** Determine if activation procedures are contraindicated | **K9** Medical contraindications to activation procedures | **5.1 Fundamental Clinical Procedures**<br>**5.1 d** Identify patient history that may affect the procedure | **3. Patient Care**<br>Identify the need to adapt the EEG procedure according to the information provided including:<br>1. additional activation techniques<br>2. omit activation procedures based on contraindications<br>3. additional recording techniques | **3.4**<br>**Obtain a full, concise history** relevant to the investigation and record this information accurately.<br>3.5<br>Discuss and confirm the patient's current medication with the patient and/or caregivers, and record any recent variations.<br>3.6<br>Accurately assess the patient's present condition based on all of the available information, including case notes, direct observation and questioning of patient and caregivers.<br>3.7<br>After obtaining the patient's history, the original plan is reviewed and is deemed appropriate or is adjusted as necessary | **6. Patient History**<br>**a.** Determine if activation procedures are contraindicated<br>**b.** Take a patient history gathering information from a chart if available, and by interviewing the patient or caregiver.<br>**c.** Obtain patient information including:<br>**1.** full name<br>**2.** age<br>**3.** hospital or clinic ID number<br>**4.** current symptoms or complaints and indication for the test<br>**5.** referring physician & family physician<br>**6.** recording time<br>**7.** date<br>**8.** technologist's name or initials<br>**9.** any allergies or sensitivities |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | | |
| | **ID1-2** Prepares a basic data sheet that includes name, age, ID number, doctor, recording time, date, technologist name or initials | **K-1** Elements of a patient history **K-44** Allergies and sensitivities | **5.1 Fundamental Clinical Procedures** **5.1 c** Obtain relevant patient history | **3. Patient Care** **a.** obtains relevant clinical history including: 1. personal medical history, 2. description of episode, 3. medications, 4. family history 5. last meal 6. handedness **b.** Indication for the test | | |
| | **ID3** Documentation of patient & family history | **T-1 K-1** Obtain patient health information and additional information from medical records, patient, family or caregivers in order to plan recording strategies and avoid adverse side effects | **3.4 Recording and Documenting** **3.4 a** Maintain comprehensive records **3.4 b** Prepare written technical impression for interpreting physician **3.4 c** Utilize information and archival systems **3.4 d** Maintain confidentiality of records with appropriate access **5.1 Fundamental Clinical Procedures** **5.1 d** Identify patient history that may affect the procedure | | | **7. Document Management: a.** Maintain comprehensive records **b.** Document patient history and plan recording strategy to avoid adverse side effects using information from patient record (chart) and information from family or caregivers **c.** Maintain patient confidentiality and privacy **d.** Document a technical description of the recording |
| | **ID4** Documents list of current medication & time of last dosage | **K-3** Effects of medications on patients and recordings | | | | **8. Medications** Document a list of current medications and time of last dosage. |
| | **ID5** Documents time of last meal | | | | | **9. Document time of last meal.** |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | **ID6** Documents time & date of last aura & circumstances of last seizure or symptoms | | | | | **10. Last Seizure** If patient is suspected of seizure, document aura & circumstances of last seizure or symptoms |
| | **ID7** Documents the specifics of the patient's mental, behavioral & consciousness states | **K-5, 6, 7** Psychiatric Disorders, toxic metabolic and infectious diseases, head trauma, and **K-16** Cognitive limitations **IC6** Accommodate for disabilities or special needs | | **3. Patient Care** Identify the need and demonstrate the testing of the patient's responsiveness and memory during suspected electrographic seizures | | **11. Patient State** Document patient's state, mental, behavioral & level of consciousness (e.g. alert, bright, cooperative, confused, disoriented, comatose, uncooperative, combative, unresponsive, obtunded, etc.) and accommodate for disabilities and special needs |
| | **ID8** Diagrams skull defects or anomalies if any | | | | | **12. Skull Condition** Document any skull defects or anomalies |
| | **ID9** Diagrams any modifications to the International 10-20 electrode placements | | | | | **13. Modifications to the 10-20 System** If modifications of the 10-20 System, diagram changes on the recording for the interpreter |
| **Clinical Skill Domain 3: Practical Underlying Science Knowledge** | **IA11** Taking appropriate precautions to ensure electrical safety | **K-37** Electrical safety techniques | | | | **14. Patient Safety** Take appropriate precautions to ensure electrical safety and patient safety during the EEG recording |
| | **IF1-6** The technologist has basic knowledge of digital | **K-23** Characteristics of a differential | | **1. Core Knowledge** a. Describe analogue to digital conversion | **EEG Equipment Characteristics and Classification** | **15. Digital instrumentation** Identify, explain and |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | EEG technology<br>**IO1** Applies principles of electronics and mathematics to recording by knowledge of differential amplifiers, computing voltage and frequency of waveforms, calculating the duration of waveforms, polarity of waveforms, impedance and analog to digital (A-D) conversion<br>**IP1-8** Knows how waveform displays are affected by 60 Hz filter, filter settings, sensitivity settings, time-base (paper speed), referential and bipolar montages, digital filters vs analog filters, electrode types and electrode material composition and malfunctioning equipment.<br>**IG1-5** Verifies & documents that the digital EEG instrument is in good working condition (calibrating amplifiers, adjusting | amplifier (e.g. polarity, CMRR)<br>**K-30** Effects of instrument settings (e.g. filters, display gain, time base)<br>**K-33** Digital instrumentation concepts (e.g. reformatting, sampling rate, video, calibration, post-acquisition review)<br>**K-40** Waveform analysis (e.g. frequency, duration, voltage)<br>**K-20** Conditions affecting impedance<br>**K-31** Polarity and localization techniques<br>**K-32** Montage modifications<br>**K-20** Conditions affecting impedance<br>**K-24** Range of impedance values<br>**K-24** Range of standard impedance values | | recording techniques<br>b. Identify bandwidth and frequency response characteristics<br>c. Identify and explain the implication and use of frequency filters<br>d. Explain the function and purpose of differential amplifiers<br>e. Define common mode rejection ratio and understand its function and purpose<br>f. Identify the recording parameters and how they differ from display parameters including sensitivity and filters<br>g. Identify advantages and disadvantages of different types of electrodes<br>h. Identify the need to chloride and re-chloride silver electrodes<br>i. Discuss the chemical and electrolytic process to chloride and de-chloride silver electrodes<br>j. Explain the measurement of impedance<br>k. Identify the importance of equal and low impedances in electrode application<br>**4. Equipment**<br>**a.** Amplifiers | The characteristics and specifications for digital recording systems.<br>The characteristics of electrodes and transducers.<br>The electrical safety classification of equipment.<br>Principles and practice for patient isolation with reference to equipment class.<br>EEG Equipment Operation<br>Principles underlying the operational requirements of a recording system.<br>The structure and function of the component parts of a conventional multi-channel EEG, including:<br>•Amplifiers<br>•Filters and their effect on the recorded electrical activity<br>•Display systems: different types, detailed characteristics and criteria for selection<br>•Principles of digitalization<br>Equipment operation<br>Principles of the operation of EEG equipment. | describe appropriate use of the following:<br>**a.** differential amplifier **b.** polarity & localization<br>**c.** common mode rejection **d.** filters and use<br>**e.** sensitivity<br>**f.** display gain<br>**g.** time-base<br>**h.** reformatting montages<br>**i.** sampling rate<br>**j.** calibration<br>**k.** impedance low & balanced *(below 5K Ohms)*<br>**l.** video monitoring<br>**m.** post-acquisition review **n.** frequency<br>**o.** duration calculations<br>**p.** voltage calculations<br>**q.** montages<br>**r.** electrode types, impact on recorded potentials and maintenance<br>**s.** electrode material composition and impact on recorded potentials<br>**t.** verifies and documents that the equipment is in good working condition<br>**u.** malfunctioning equipment |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | filters, & sensitivity appropriately)<br>**IE5** Verifies that electrode impedance is low & balanced (below 5K ohms) | | | 1. identify and explain the implication and use of frequency filters on the EEG<br>2. identify the routine acquisition parameters<br>3. explain the technique of referential recording<br>4. explain the importance of the ground electrode<br>**b. Software**<br>1. enter identifying data and other data, according to workplace protocol<br>2. start, pause and end recording<br>3. alter recording and display parameters<br>4. annotate recording during and after recording<br>5. display data from any added electrodes<br>6. edit and archive recordings | Amplifier input connections for bipolar and referential (common reference and average reference) recording techniques.<br>Methods of derivation and design of montages.<br>Lateralization and localization of normal variants and abnormal phenomena and their effect on the EEG display.<br>Characteristics and origins of physical and biological artefacts, methods of identification and means of elimination.<br>The use of machine controls, including their effect on the original signal and their use to highlight salient features.<br>Principles and procedures for the selection and use of additional electrodes and transducers.<br>Principles underlying the range of polygraph recording methods and for determining the selection of particular methods.<br>Relationship of the annotation to data on | **v.** manage operation of equipment software<br>**w.** perform routine recording procedures<br>**x.** analog to digital conversion, dwell time and sampling rate<br>**16. Re-formatting Digitally Recorded EEG Data**<br>**a.** explain how re-formatting of EEG data after the recording is possible<br>**b.** explain role of system reference in reformatting data |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | recording.<br>The principles relating anomalies to current clinical problem/previous findings.<br>Calibration of EEG equipment<br>The principles of standard calibration procedures.<br>The purpose of calibrating records. | |
| | **IM3** Medical terminology and accepted abbreviations | **K2** Medical terminology | | | | **17. General medical terminology**<br>**18. Neurodiagnostic terminology** |
| | **IQ1-4** Recognizes normal, normal variant, awake, asleep, patterns at any age, abnormal awake and asleep patterns at any age, EEG patterns for level of consciousness and clinical seizure patterns | **K-10** Electrographic Correlates to clinical entities<br>**K-29** EEG Patterns | | | | **18. Recognize Normal EEG Patterns:** Normal, awake and sleep, adult, and pediatric EEG recordings<br>**19. Identify EEG Clinical Correlates:** Electrographic correlates to clinical entities **20. Identify Abnormal EEG patterns** in neurological disorders, seizures, vascular disorders, and brain injury |
| | **IM1** Functional neuroanatomy and neurophysiology | **K-8** Neuroanatomy | | Neuroanatomy:<br>Define major anatomical structures and function of the major brain | **3.4 Knowledge Specification Anatomy and Physiology** Relevant to EEGs | **21. Neuroanatomy:** Recognize and identify major anatomical structures and function |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | regions | Development and maturation of the central nervous system.<br>Major anatomical divisions of the nervous system: brain, cerebellum, brainstem and spinal cord.<br>Basic functional divisions of the nervous system.<br>Anatomy and physiology of: cerebral circulation, cerebrospinal fluid, cortical and sub-cortical structures and other body systems.<br>Diagrammatic representation of cortical and sub-cortical structures, brainstem, ventricles, meninges, hemispheres and lobes, reticular formation, cranial nerves, thalamus and internal capsule.<br>Motor and sensory pathways – both central and peripheral.<br>Pathology of the brain.<br>The aetiology (UK spelling of etiology) and symptomology of common pathological processes and the role of EEG in their investigation.<br>Clinical features of disease of the nervous | of the major brain regions<br>**22. Neurophysiology**<br>Recognize and Identify the physiological basis of EEG waveforms |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | system.<br>Effect of cardiorespiratory and metabolic disorders on the EEG.<br>Effect and use of prescribed and non-prescribed drugs in relation to conventional EEG recordings. | |
| | | **K-18** Metric System | | | | **23. Metric System** (US only) |
| | **IM2** Medication effects on EEG background and waveforms | **K-3** Effects of medications on patients and recordings | | **1. Core Knowledge**<br>Describe the effects of diseases of the nervous system on the EEG including but not limited to:<br>**a**. Epilepsy<br>**b.** Inflammatory processes/infections<br>**c**. Neuro-degenerative disorders<br>**d**. Metabolic disorders<br>**e.** Drug effects<br>**f.** Space occupying lesions<br>**g.** Cerebrovascular disease | **Medication:**<br>Modes of drug delivery, action and side effects.<br>Organizational procedures for drug administration. | **24. Medication effects** on EEG background and waveforms |
| | **IM4** Signs, symptoms and EEG correlates for adult neurological disorders<br>**IM5** Signs, symptoms and EEG correlates for pediatric neurological disorders<br>**IM6** seizure manifestations, classifications and EEG correlates | **K-4** Neurological Disorders (e.g. seizures, tumors, vascular disease)<br>**K-6** Toxic/metabolic and infectious diseases | | | | **25. Signs, Symptoms and EEG Correlates to Adult and Pediatric Neurological Disorders:**<br>**a.** seizures<br>**b.** tumors<br>**c.** vascular disease<br>**d.** toxic/metabolic & infectious diseases |
| | **IM7** Psychiatric and psychological disorders | **K-5** Psychiatric Disorders | | | | **26. Psychiatric & psychological disorders**<br>Recognize psychological disorders identified in patient history and physical |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | **K-7** Head trauma | | | | **27. Head trauma** Recognize EEG patters associated with head trauma. Appropriately place electrodes when patients have suffered a head trauma. |
| | **IM8** Other knowledge as detailed in the ABRET EEG Technology Practice Analysis | | | | | |
| | | | | **1. Core Knowledge**: a. Identify the use of EEGs during surgical procedures | | **28. EEG in Surgery** Identify the use of EEGs during surgical procedures |
| **Clinical Skill Domain 4: Recording Strategy, Procedural Steps and Post-Study Steps** | **IA2** Cleaning electrodes after each procedure **IA3** Following Universal Precautions and Infection control procedures **IA9** Comply with Lab Protocols for hazardous material handling procedures | **K-19** Infection control **K-22** MSDS/OSHA standards | **1.1 d Comply with employer policies and directives** **5.1 Fundamental Clinical Procedures** **5.1 e** Prepare the physical area for the patient **5.1 f** Position the patient | **3. Patient Care** **a.** position patient for adequate accessibility, relaxed state and patient comfort **4. Equipment** Electrodes **a.** Prepare and clean electrodes for use according to WH&S and IC regulations **b.** store electrodes appropriately | **3.4 Knowledge specification: Patient Care** The importance of ensuring identity of the patient and that the identification of the patient is correct on all documentation. The basic assessment of the condition of patients. The ways in which the patient's condition may have an impact on the planned investigation. The principles and methods of effective communication with patients and escorts. The reasons why it is important to put the patient at ease. | **29. Infection control** Clean electrodes, hard and soft surfaces in the lab according to World Health Organization recommendations, national standards, regional standards and hospital or clinic protocols. Use personal protective wearables such as disposable gloves for head measurement, electrode preparation, application, and removal. Use masks and gowns when indicated. Dispose of contaminated materials appropriately. **30. Comply with national and regional** |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | The sorts of questions the patient may have and the appropriate answers to such questions.<br>The required position of the patient and how to help the patient become more comfortable.<br>How to maintain the patient's sense of dignity and self-esteem during the investigation.<br>Guidelines for responding to ictal events or disturbed states.<br>Infection control/hand hygiene issues related to patient-care.<br><br>**3.4 Knowledge Specification Equipment maintenance and disposal**<br><br>Principles of electrode sterilization and cleaning methods.<br><br>Health and safety requirements for disposing of consumables. | **safety standards** for staff and materials used in the work environment such as MSDS/OSHA standards (US) to protect employees from hazards or harm.<br>**31. Universal Precautions:** Make use of infection control precautions with all patients. **32. Comply with lab protocols**, **policies and procedures** while preparing the physical area for the patient<br>**a.** Prepare and clean electrodes<br>**b.** Store electrodes properly **33. Position patient** safely allowing for adequate accessibility, relaxed state and patient comfort |
| | **IA5** Recognize and respond to life threatening situations | | | | | **34. Emergencies:** Recognize and respond to life |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | **IA6** Maintain CPR credential | | | | | threatening situations including maintaining a CPR credential |
| | **IA7** Follow Lab Protocols for sedation | | | | | **35. Sedation:** Follow lab protocols on sedation |
| | **IA8** Comply with Lab Protocols for Emergency & Disaster situations | | | | | **36. Disaster and emergency:** Be aware of and comply with lab protocols for emergency & disaster situations plans |
| | **IA10** Maintaining equipment | **Domain III T-3** Ensure that schedule maintenance of equipment is preformed | **4.1 Fundamental Equipment** Procedures<br>**4.1 a** Operate only approved equipment while performing procedures<br>**4.1.b** Operate equipment in accordance with manufacturers' specifications<br>**4.2 Equipment Quality Control**<br>**4.2 a** Regularly inspect equipment for functional integrity<br>**4.2 b** Ensure mechanical functionality of equipment<br>**4.2 c** Perform regular quality control as required by the manufacturer<br>**4.2 d** Calibrate recording equipment<br>**4.2 e** Ensure quality control for leakage current<br>**4.2 f** Perform basic troubleshooting; correct or report as appropriate<br>**4.2 g** Ensure maintenance of filer and sensitivity | **2. Preparation:**<br>**a.** Perform routine maintenance of equipment.<br>**b.** Prepare and check equipment is working according to manufacturer's specifications.<br>**c.** Identify and correct minor equipment faults.<br>**d.** Identify the process for repair of more complex faults. | | **37. Fundamental Equipment Maintenance**<br>**a.** Perform routine cleaning, system checks, minor repairs & maintenance of equipment.<br>**b.** Schedule periodic maintenance & document regular electrical safety checks |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | control operations<br>**4.2 h** Evaluate quality control and take corrective action as required | | | |
| | **IE1** Follows the International 10-20 System of Electrode Measurement & Placement<br>**IE3** Prepares the patient's scalp to lower impedance prior to electrode applications<br>**II6** Applies additional electrodes to localize abnormalities<br>**II7-8** Monitors respiration if appropriate and ECG rhythms for abnormalities | **T-1** Prepares the patient by:<br>**a.** Measuring and marking the patient's head to determine electrode sites<br>**b.** Prepares the sites for electrode placement in order to reduce impedance<br>**c**. Securely applies the electrodes; and<br>**d.** Checks impedance to ensure electrode integrity<br>**K-17** Electrode placements (i.e.10-20, T1, T2)<br>**K-32** Montage modifications | **5.2 Obtain Standard Recordings**<br>**a.** Measure and mark head using International 10/20 Electrode Placement System<br>**b.** Mark sites for placement for digital reference electrodes<br>**c.** Mark site for placement of ground electrodes<br>**d.** Prepare electrode sites<br>**e.** Place electro-occulogram (EOG) electrodes using conductive paste or collision and electrolyte<br>**f.** Place electrocardiogram (ECG) electrodes<br>**g.** Ensure electrode impedances are balanced between 100 and 5000 ohms during the recording<br>**h.** Obtain a minimum of 20 minutes recording, including simultaneous ECG and EOG channels not including activation procedures | **5. Electrode Application:**<br>a. accurately apply electrodes according to the 10/20 Electrode Placement System<br>b. measure and mark the patient's head according to the 10/20 Electrode Placement System<br>c. explain the consequences of inaccurate electrode measurement and placement<br>d. prepare skin for application of recording electrodes adhering WH&S and IC regulations<br>e. explain the importance of good electrode application<br>f. identify advantages and disadvantages of different types of application – surface electrodes with paste, surface electrodes with Collodion, sub-dermal needle electrodes, other<br>g. demonstrate appropriate stability of electrode application for | **Core Criteria:**<br>2.1<br>Check that the equipment selected is in a safe condition and operates correctly, including all relevant peripheral devices.<br>2.2<br>Ensure that there is adequate available storage media for the proposed investigation.<br>2.3<br>Ensure that default settings are appropriate including sampling rate, number of channels enabled, etc.<br>2.4<br>Ensure that recording parameters are checked and appropriate, e.g. sensitivity, frequency filters, etc.<br>2.5<br>Perform an auto calibration/amplifier integrity check. (before the EEG only)<br>2.6<br>Assess sensitivity using a square wave signal, testing all channels over a range of settings.<br>2.7 | **38. Electrode Application:** Measure and apply electrodes using the International 10-20 System of Electrode Placement or 10-10 System, T1, T2, system reference electrode, ground/common electrode, EOG, ECG/EKG, EMG and additional electrodes as needed, with a margin of error of less than 1 cm per chain of electrode placements.<br>**a.** Monitors ECG/EKG routinely and respiration, EMG or other artifacts when needed.<br>**b.** Explain the importance of good electrode placement and the consequences of inaccurate electrode measurement and placement<br>**c.** Identify advantages and disadvantages of different types of application – surface electrodes with paste, surface electrodes with Collodion, sub-dermal |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | the length of recording<br>h. apply additional electrodes where appropriate<br>i. identify and implement infection control procedures<br>j. observe and apply standard precautions for contact, droplet and airborne infection risks when applying, removing and cleaning electrodes | Check the photic stimulator is functioning and assess the accuracy of the photic marker.<br>2.8<br>Assess the display speed and check the accuracy of the time marker.<br>2.9<br>State the procedure for recording, reporting and rectifying equipment faults in accordance with departmental policy.<br>2.10<br>Produce a formal record of machine performance (relating to 2.6 – 2.10).<br>2.11<br>Ensure the necessary types and quantities of consumables are available for the planned investigation.<br>Specific Criteria: Portable EEG<br>2.12<br>Ensure equipment and accessories are checked in the base department before transportation for off-site recordings<br>3.8 Accurately mark electrode sites in accordance with the recommended | needle electrodes.<br>**d.** demonstrate appropriate stability of electrode application for the length of recording<br>**39. Prepare electrode sites** to reduce impedance<br>**40. Securely applies electrodes** with collodion or paste method<br>**41. Checks impedance** to ensure electrode integrity |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | placement system, ensuring appropriate accuracy with electrode distances (within +/- 5mm).<br>3.9<br>Attach electrodes and transducers correctly and securely ensuring appropriate accuracy (within +/-5mm).<br>3.10<br>Ensure leads are appropriately and securely positioned and connections to the head-box are checked as correct.<br>3.11<br>Assist the patient into a position that is comfortable (as per local procedures) to optimize the quality of the recording.<br>3.12<br>Confirm that contact impedances are appropriate to electrode type and to the patient.<br>3.13<br>Perform preparation efficiently (e.g. co-operative adult preparation ≤ 30 minutes, approximately).<br>**3.4 Knowledge Specification Selection preparation and** | |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | **placing of electrodes for EEG**<br>Central nervous system: maturation, detailed anatomy and physiology.<br>Pathophysiological conditions of the central nervous system, aetiology (etiology: study of causation) and symptomology.<br>Electrode characteristics:<br>•Electrode potential<br>•Polarization<br>•Electrode impedance and its effect on data<br>•Silver/silver chloride electrodes<br>Maintenance of electrodes.<br>Reasons for selection of electrodes.<br>Standard measurement/placement systems of electrodes and application to include International 10-20 system and Maudsley (or Modified Maudsley) system.<br>Electrode/transducer characteristics and method of application.<br>Impedance measurement. | |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | **IE2** Adjusts the International 10-20 System to accommodate for skull defects or anomalies | | | | | **42. 10-20 Modifications** Adjust or modify 10-20 System placements to accommodate for skull defects or anomalies |
| | **IE4** Applies electrodes appropriately using paste or collodion & electrolyte | **K-21** Electrode application techniques | **4.1 c** Select correct electrodes | | | **43. Applies electrodes *appropriately*** using paste or collodion |
| | **IH1** Standard EEG recording is obtained according to **ACNS Guidelines** including: 20 min minimum length; eye opening and closing to check for reactivity; hyperventilation for 3 mins if not contraindicated; photic stimulation at frequencies appropriate for history & reactivity; mental stimulation assessment procedures; checks for impedance when needed; natural drowsiness & sleep if possible: notations of montage, filters, sensitivity, time base, & notes of observed behavior, clinical seizure manifestations, movements, & | **K-13** Components of an EEG procedure | **5.2 i** Utilize longitudinal bipolar, transverse bipolar (coronal), and referential montages<br>**5.2 j-k** Utilize optimal filter, sensitivity and time base settings<br>**5.2 l** Utilize additional physiological monitors where appropriate<br>**5.2 m** Perform hyperventilation<br>**5.2 n** Perform photic stimulation<br>**5.2 o** Perform eye opening/closing<br>**5.2 p** Perform sleep EEGs<br>**5.2 q** Correct and or monitor physiological and non-physiological artifacts<br>**5.2 r** Annotate relevant information throughout the recording<br>**5.2 s** Remove electrodes and clean areas of application | **6. Recording**<br>**a. Perform EEG Recording**<br>1. connect electrodes to the pre-amplifier according to electrode placement<br>2. arrange leads &pre-amplifier to minimize environmental artefacts<br>**b. Identify the appropriate electrode impedance for EEG**<br>1. define the required impedance level for recording<br>2. measure electrode impedance<br>3. identify and adjust impedance levels when required<br>**c. Perform calibration and machine check**<br>1. record a calibration signal for appropriate length of time before and after recording<br>2. define the value of the input calibration signal | Core Criteria:<br>4.1 Employ a range of montages appropriate to the clinical problem. For digital recordings, this includes referential data checks at the beginning and end of the recording (as a minimum)<br>4.2 Continuously monitor the results of the investigation, reviewing for validity, accuracy and clinical significance<br>4.3 Use appropriate control settings during the investigation to optimize the identification of clinically useful data<br>4.4 Accurately and legibly annotate the EEG recording<br>4.5 Record a single channel of electrocardiogram | **44. Standards:** Performs EEG study according to standards set by national agencies or physician or technologist/scientist organizations in clinical neurophysiology such as the ACNS in the US or your national Standards and Guidelines<br>**a.** make use of montages as needed including routine referential and bipolar montages and common average reference montages, Laplacian source derivation or modified montages as needed to enhance abnormalities.<br>**b.** use calibration when available or alternative system check to verify system |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | artifacts throughout the recording.<br>**II5** Encourages drowsiness and sleep<br>**IL2** Describes clinically specific behavior<br>**IL3** Documents sedation used, dosage and effects (if applicable)<br>**IL4** Review EEG for appropriate documentation of amplifier settings and montage changes | | | 3. explain the importance and the information provided by the calibration signal including display alignment, sensitivity, linearity, centering, damping, high frequency filters, low frequency filters, time constant, display speed, machine noise<br>4. all electrode check – explain the relevance and appropriateness<br>**d. Define the machine settings used for EEG**<br>1. define the machine settings including sensitivity, filters, display speed<br>2. explain the relevance of the machine settings to the recording<br>3. use machine settings according to departmental protocols<br>4. alter machine control settings when appropriate 5. set video and audio recording device to capture patient appropriately<br>**e.** Identify the montages used for EEG recording<br>1. define The EEG Polarity Convention<br>2. explain the | Core **Criteria: Hyperventilation**<br>5.1 Review the data obtained to assess the relevance of the proposed activation procedure<br>5.2 Establish that the proposed activation procedure is not contraindicated and is performed to department guidelines<br>5.3 Provide the patient with a clear and accurate explanation of the procedure and encourage them to clarify any areas of concern<br>5.4 Treat the patients in a manner which is likely to encourage cooperation and confidence and maintain their dignity<br>5.5 Obtain consent to perform the procedure<br>5.6 Make the immediate environment suitable for the intended activation procedure<br>5.7 Position the patient suitably to perform the activation procedure<br>5.8 Implement the activation procedure correctly and safely in accordance with | integrity<br>**c.** record long enough to ensure the patient has an opportunity to achieve light sleep<br>**d.** make use of video and audio recording of patient during EEG if available<br>**e.** use sleep deprivation when appropriate<br>**45. Administration of activation procedures** of hyperventilation (when not contraindicated), photic stimulation, eye opening & closing & encouraging sleep when possible<br>**46. Annotations:** Makes notations of patient sedation if given, instrument settings if not automatically noted and observed behaviors, symptoms, movements, artifacts, clinical seizure manifestations, and level of consciousness throughout the recording, especially clinically significant behaviors. Annotate instrument settings if not automatically noted on recording |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | **II1** Makes customized changes to the standard EEG procedure to evaluate reasons for EEG referral, patient history or observed waveforms.<br>**II2** Utilizes techniques to bring out or enhance clinical symptoms<br>**II3** Selects appropriate montages for enhancement of abnormalities<br>**II4** Selects appropriate instrument settings | **T-3** Modify or adjust the recording strategy and/or instrument parameters based on the technologist's evaluation of recorded data to ensure a complete, comprehensive and technically satisfactory study | **5.3 Customize/Adapt Recording Procedures**<br>**a.** Adapt procedures based on patient condition<br>**b** Adapt procedures for neonatal patients<br>m9**c.** Adapt procedures for pediatric patients<br>**d.** Adapt procedures for Intensive Care Unit (ICU) patients<br>**e.** Assist in adaptation of procedures for patients who have injury resulting in burns or trauma<br>**f.** Adapt procedures for electrocerebral silence (ECS) recording<br>**g.** Perform visual reactivity tests for patients with impaired levels of consciousness<br>**h.** Perform auditory reactivity tests for patients with impaired levels of consciousness<br>**i.** Perform somatosensory reactivity tests for patients with impaired levels of consciousness<br>**j.** Perform painful stimulation reactivity tests for patients with impaired levels of consciousness<br>**k.** Adapt procedures as required during the recording<br>**l.** Respond to seizures | importance of the system reference electrode<br>3. identify and explain different montage derivation types including bipolar, common reference, common average reference, *Laplacian* source derivation reference,<br>4. advantages and disadvantages of different montage derivation types and best use for different montage derivation types<br>5. localization for different montage derivation types<br>6. identify pitfalls of different common reference positions<br>**f.** Identify different montage configurations and explain the advantages and disadvantages or best use for each.<br>**g.** use a range of pre-set recording montages including anterior-posterior, transverse and common reference montages<br>**h.** Create and use independent montage or alter existing montage in | conventional protocol and encourage the patient to cooperate<br>5.9 Annotate details relevant to the procedure (time, effort, eyes open/closed, etc.)<br>5.10 Continuously monitor the activation procedure and accurately record change in the condition of the patient<br><br>**Photic Stimulation:**<br>6.1 Review the data obtained from the initial recording to assess the relevance of the proposed activation procedure<br>6.2 Establish that the proposed activation procedure is not contraindicated and is performed to department guidelines<br>6.3 Provide the patient with clear and accurate explanation of the procedure and encourage them to clarify any areas of concern<br>6.4 Treat the patient in a manner which is likely to encourage cooperation, confidence and maintain their dignity | **47. Recording Strategy:** Follow technical criteria for recording and modify or adjust the recording strategy and/or instrument parameters based on the technologist's evaluation of recorded data to ensure a complete, comprehensive and technically satisfactory study, adapting the study based on the patient's age, status and condition:<br>**a.** Neonatal<br>**b.** Pediatric<br>**c.** ICU patients<br>**d.** Injury resulting in burns or trauma<br>**e**. Perform visual, auditory, somatosensory and painful stimulation reactivity tests for patients with impaired levels of consciousness<br>f. Adapt procedures during the recording as required<br>**g.** Respond to and document patient seizures<br>**48. Electrocerebral Inactivity: a.** Perform suspected |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | appropriate setting<br>**i. Perform activation techniques**<br>1. explain and demonstrate the use of activation techniques appropriately including visual, hyperventilation, photic stimulation, sleep deprivation, auditory, tactile, and other as indicated<br>2. identify contra-indications for activation procedure<br>3. instruct the patient for the activation procedure<br>4. identify patient response to activation procedures<br>5. identify and respond to patient response where necessary<br>**j. Record an EEG**<br>1. define appropriate length of recording<br>2. identify departmental EEG procedure protocol<br>3. apply independent clinical judgement for recording procedure where appropriate<br>**k. Annotate the recording**<br>1. annotate accurately and clearly, montage and instrument settings, patient clinical state and clinical events, clinical | 6.5 Obtain consent to perform procedure<br>6.6 Make the immediate environment suitable for the intended activation procedure<br>6.7 Position the patient suitably to perform the activation procedure<br>6.8 Implement the activation procedure correctly and safely in accordance with conventional protocol and encourage patient to cooperate<br>6.9 Annotate details relevant to the procedure (stimulation frequency, eyes open/closed, etc.)<br>6.10 Continuously monitor the activation procedure and accurately record changes in the condition of the patient<br><br>**Core Criteria: Polygraphy**<br>8.1 EEG (at least Fp2-C4, C4-O2, Fp1-C3, C3-O1, C4-CZ and CZ-C3)<br>8.2<br>Eye movement (vertical and horizontal)<br>8.3<br>Respiration<br>8.4 | electrocerebral silence (electrocerebral inactivity) ECS/ECI studies according to specifications set by ACNS (US) or national organization of clinical neurophysiology |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | changes or lack of changes during the recording, artifacts and steps to eliminate or reduce<br>**7. Additional Recording Measurements**<br>**a.** Record ECG<br>1. identify the importance of recording ECG in conjunction with the EEG<br>2. correlate to EEG<br>**b.** Record respiration<br>1. identify when recording respiration in conjunction with the EEG is required<br>2. correlate to EEG<br>**b. Record Eye movements**<br>**1.** identify when recording eye movements in conjunction with the EEG is required<br>2. correlate to EEG<br>**c. Record surface EMG**<br>1. identify when recording surface EMG in conjunction with the EEG is required<br>2. correlate to EEG<br>**d. Record body/limb movement**<br>1. identify when recording body/limb movement in | Surface EMG<br>8.5<br>Tremor<br>8.6<br>Printouts that demonstrate the physiological effects of each polygraphy channel with corresponding annotation.<br><br>**3.4 Knowledge Specification Hyperventilation**<br>The physiology of hyperventilation.<br>The effects of age of hyperventilation.<br>Variation with blood sugar levels.<br>EEG abnormalities and activation procedures.<br><br>**Intermittent Photic Stimulation**<br>Rationale of procedure for intermittent photic stimulation.<br>Risks to patients and others.<br>Normal variation of responses to intermittent photic stimulation.<br>Atypical and abnormal responses to intermittent photic stimulation. | |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | conjunction with the EEG is required<br>2. correlate to EEG<br>**9. Completing the EEG**<br>a. Check electrode integrity<br>b. Validate recording on completion<br>c. Remove electrodes according to different applications according to WH&S and IC regulations and patient comfort.<br>d. Remove electrolyte from patient<br>e. Assist patient as required<br>f. Inform patient of the process for obtaining results<br>g. Dispose of materials according to waste management, WH&S and IC regulations<br>h. Clean recording electrodes in accordance with WH&S and IC regulations | Alternative methods of intermittent photic stimulation.<br>Characteristics of intermittent photic stimulators.<br>**Sleep activation**<br>Value in relation to clinical problem.<br>Stages of sleep.<br>Medication/deprivation. | |
| | **IL1** After the recording is complete, | **Domain III T-1** Remove the | **4.1 d** Disinfect non-disposable surface | | **Core Criteria:**<br>7.1 | **49.** Remove electrodes, clean |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | the technologist removes paste/glue from the patient's hair & scalp | electrodes, clean electrode sites, clean and disinfect electrodes and equipment | electrodes | | Completely remove electrodes and transducers and carefully clean the sites with minimum discomfort to the patient.<br>7.2<br>Reassure the patient and give them sufficient time to recover from the investigation prior to leaving the department.<br>7.3<br>Clearly and accurately inform the patient of the procedure for notification of the results from the investigation.<br>7.4<br>Treat the patients in a manner which is likely to preserve their dignity, confidence and self-esteem throughout the investigation.<br>7.5<br>Clean equipment (and where appropriate sterilize it), in accordance with local policy, and leave it in a condition suitable for re-use.<br>7.6<br>Dispose of consumables in a safe manner and place.<br>7.7 | electrode sites removing paste/collodion from patient's hair and scalp. Clean and disinfect electrodes before use according to World Health Organization recommendations and hospital or clinic protocols. |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | Adhere to local infection control, hand hygiene policies and procedures throughout the investigation.<br>7.8<br>Ensure annotations made to recordings and other patient documentation are accurate, legible and complete.<br>7.9<br>Manipulate the data including measurements of frequency and amplitude, re-montaging to enhance specific features, etc. Demonstrate skills in editing a montage, searching for events, the effect of changing machine parameters and setting up a new montage.<br>7.10<br>Promptly prepare a concise, accurate factual report covering the procedures employed, neurophysiological findings and clinical events and draw the clinician's attention to features considered to be of clinical importance. | |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | 7.11<br>Establish the degree of urgency for the clinical report and forward the factual report to the clinician within the required time. | |
| | | **K-12** HIPAA Standards<br>**K-22** MSDS/OSHA standards | | | | **50.** Follows policies, procedures, MSDS/OSHA and HIPAA standards |
| | | **Domain III T-2** Process acquired data<br>**K-42** Media management (copy, storage, archive, etc.) | | Managing the recorded data<br>• Edit recording<br>• Archive recording<br>• Maintain database of recording | | **51.** Process acquired data, and manage media (spike-detection software, copy, storage, archive, etc.) |
| | **IJ1-4** Follows technical criteria for recording electrocerebral inactivity; neonatal EEG, pediatric EEG and intensive care or cardiac care patients | **K-14** Age-specific criteria | | | | **52.** Customizes recording to address specific patient needs and age-specific criteria including neonatal, pediatric, intensive care and cardiac care patients. |
| **Clinical Skill Domain 5: Observational Skills and Situational Awareness** | **IA4** Attending to patient needs appropriately **IC1** Determines the patient's mental age, mental state & comprehension level<br>**IC2** Note the patient's overall physical condition<br>**IC6** Accommodate for disabilities or | **T-4** Document patient behavior and clinical events to provide additional information for the interpretation<br>**K-34** Significant patient behaviors and clinical events (e.g. changes in level | **3.2 Patient Assessment and Intervention**<br>**3.2 b** Assess patient's level of understanding of the procedure and adapt communication, assessment and screening appropriately<br>**3.2.c** Adapt procedure according to patient's mobility and stability<br>**3.2 d** Assess patient for | | | **53. Observes patient during recording** and appropriately attends to needs including the special needs of physically or mentally handicapped patients. |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | special needs<br>**IC8-9** Document unusual or inappropriate behavior suggestive of seizure or other event, need for restraints or emergency intervention | of consciousness, body movements, episodes)<br>**K-16** Cognitive limitations | contraindications to the procedure<br>**3.2 e** Verify patient's consent for the procedure<br>**3.2 f** Recognize and respond to changes in the patient's physical condition, behaviors and level of consciousness<br>**3.2 g** Recognize and respond to changes in the patient's vital signs<br>**3.2 h** Perform procedures in a manner that maintains patient's dignity<br>**5.1 g Recognize clinical signs relevant to EEG assessments of**:<br>1. Ability to follow commands<br>2. Diaphoresis<br>3. Edema<br>4. Eye movements and Involuntary movements<br>5. Level of consciousness<br>6. Medical devices | | | |
| | | **K-10** Electrographic Correlates to clinical entities<br>**K-14** Age specific criteria<br>**K-29** EEG Patterns | **5.4 Analyze Recording .a.** Recognize critical abnormalities such as ECG changes<br>Electro cerebral silence<br>Electrographic seizure<br>Epileptiform activity<br>Status epilepticus<br>Unanticipated significant focal EEG changes<br>**b.** Adapt analysis of recording as would be | | **3.4 Knowledge Specification Normal patterns of EEG and the recognition of clinical abnormalities**<br>Origin of the EEG signal.<br>Details of the variety of patterns of normal and abnormal EEG activity and normal | **54. Analyze EEG Data: a.** Apply polarity convention, knowledge of montages to localize EEG activity<br>**b.** Observe EEG data and correlates patterns with age specific developmental criteria, clinical correlates, and recognizes normal, |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | affected by the medications: Anesthetic agents Anti-convulsants Anti-depressants Anti-emetics Anti-psychotics Barbiturates Benzodiazepines Narcotics Sedatives **c.** Adapt analysis of recording as would be affected by clinical conditions: Cerebral vascular disease Dementia Drug toxicity Encephalopathies/encephalitis Head injury Metabolic disorders Migraine Seizure disorders Level of consciousness Syndromes Tumors **d.** Recognize normal and normal variant EEG patterns according to age and state of patient **e.** Recognize abnormal patterns according to the patient's age and level of consciousness **f.** Recognize effect of physical, clinical and non-physiological parameters on results **g.** Localize focal waveforms **h.** Correlate EEG with clinical seizures | | variants/phenomena. Normal and abnormal findings in electrocardiogram, electro-oculogram and other basic polygraphic recordings. Effect of natural and induced sleep on the recording. Methods of relating the findings of EEG investigations to common pathophysiological conditions and non-organic disorders. Effects of medication on the EEG. Purposes and methods of activation. Recording procedure for activation. Normal findings of activation procedures. Interaction with common pathophysiological conditions. Indications that the procedures should be discontinued. | normal variant, and abnormal EEG patterns with clinical correlates **c.** When needed the technologist relates observed patterns to the interpreting physician for his/her immediate attention **d.** monitor patient state, sleep, and movements |
| | **IA5** Recognize and respond to life | | | | | **55. Emergencies:** Recognizes and |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | threatening situations | | | | | responds to life threatening situations |
| | **IK1** Recognizes & differentiates artifact from cerebral waveforms & documents patient movements, sources of artifact. **IK2** Documents sources of artifact **IK3** Applies monitoring electrodes & records physiological artifacts such as eye movements | **K-26** Artifact monitoring, identification and elimination | | **6. Recording Recognize artifacts** **a.** identify artifacts and their source **b.** instrumental and or environmental artifacts **c.** physiological artifacts **d.** eliminate or minimize artifact | | **56. Artifacts:** Identifies recognizes & differentiates artifact from cerebral waveforms, documents, monitors or eliminates as appropriate |
| | **IK4** Routinely applies and monitors ECG/EKG | | | | | **57. Electrocardiogram rhythm channel:** Routinely applies and monitors ECG/EKG |
| | **IK5** Replaces electrodes exhibiting questionable activity, poor impedance or poor contact with the scalp or appears to be broken | | | | | **58. Electrode integrity:** Replaces electrodes exhibiting questionable activity, poor impedance or poor contact with the scalp or appears to be broken |
| | **IK6** Troubleshoots for possible electrical interference or 60 Hz noise | | | | **Fault finding identification and rectification** Principles and testing of a complete recording system and the detection and identification of equipment faults. Principles underlying | **59. Troubleshooting:** Troubleshoots for possible electrical interference or 60 Hz noise |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | the use of basic test equipment, including multi-meters and signal generators for calibration, and fault identification.<br>Procedures for the rectification of simple equipment faults.<br>Limit of responsibility in terms of rectifying faults.<br>The correct procedures for reporting faults. | |
| | | | **5.1 h** Submit recording for review | | | **60. Submit recording for review** |
| **Clinical Skill Domain 6: Clinical Reasoning/Proble m-Solving & Critical Thinking** | **IA4** Attending to patient needs appropriately<br>**IC1** Determines the patient's mental age, mental state & comprehension level<br>**IC6** Accommodate for disabilities or special needs | **K-16** Observe and note any patient cognitive limitations | **6.1 Analysis and Enhancement of Practice**<br>**6.1 a** Utilize problem-solving strategies<br>**6.1 b** Generate and evaluate effectiveness of alternative approaches to practice<br>**6.1 c** Critically evaluate performance to ensure best practice<br>**6.1 d** Manage professional and personal roles to minimize risk<br>**6 .1 e** Manage resources effectively<br>**6.1f** Assist in research-based initiatives<br>**6.1 g** Maintain awareness of changes within the Canadian healthcare environment as they affect the practice of | **10. Factual Report**<br>**a.** Describe the waveforms by means of frequency, amplitude, distribution, temporal occurrence, and reactivity<br>**b.** Format the report in a brief and concise manner including patient state, posterior dominant rhythm, background activity, normal variants, abnormal waveforms, effect of activation technique, times at which examples of uncertain or infrequent findings occur, relevant clinical observations<br>**c.** Provide technical | **3.4 Knowledge Specifications Report writing for EEG investigations**<br>Organizational requirements for report writing.<br>Normal values for frequency, amplitude and amount in relation to age.<br>Definitions of standard terms used to describe data.<br>Principles underlying the procedures for quantitative assessment of an EEG recording.<br>Effects of medication (prescribed or not) on normal values.<br>Electrographic features associated with disease. | **61. Assesses patient, appropriately**<br>**a.** attends to patient needs including special needs associated with physical or mental handicap<br>**b.** Identify the need and demonstrate the testing of the patient's responsiveness and memory during suspected clinical and electrographic seizures<br>**c.** Recognize and respond when assistance is required including:<br>1. behavioral difficulties<br>2. clinical seizure<br>3. clinical state |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | electroencephalography | report, accompanying paperwork and recording to Neurologist for reporting | Pathological conditions and changes in relation to age, space occupying lesions, epilepsy, infection, cerebrovascular disease, metabolic disorders, degenerative disorders, head injury and psychiatric disorders.<br>The correlation of normal rhythms, variants and phenomena with changing physical state.<br>Effect of stimulation on normal and abnormal values.<br>Effect of patient state on normal values including anxiety, relative hypo-glycaemia, drowsiness.<br>Appropriate storage of acquired data.<br>Organizational rules for urgency of clinical reports. | 4. ECG/EKG abnormalities<br>5. other medical emergencies |
| | **IA5** Recognize and respond to life threatening situations | **K-34** Significant patient behaviors and clinical events (e.g. changes in level of consciousness, body movements, episodes) | | **8. Interpreting the EEG**<br>**a.** Interpret EEG waveforms<br>1. identify normal waveforms including wake and sleep patterns, and normal variants appropriate for age<br>2. identify and act on patterns with | | **62. Recognize significant patient behaviors and clinical events** including life threatening situations and responds appropriately |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | appropriate activation, modification of display settings and or montage to enhance presentation and or clarification<br>3. recognize abnormal waveforms including focal, lateralizing and or generalized abnormalities<br>4. recognize localized normal and abnormal features<br>5. recognize electrographic seizures<br>6. recognize specific EEG abnormalities relating to clinical conditions including types of epilepsy, encephalopathies, generalized and focal, space occupying lesions, metabolic disorders, Creutzfeldt-Jakob Jacob Disease (CJD)<br>7. recognize EEG patterns that require immediate medical attention such as status epilepticus, subclinical non-convulsive seizures, electro-cerebral silence<br>8. recognize ECG patterns that require immediate medical attention such as significant cardiac rhythm disturbance | | |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | identify expected changes with relevant medications | | |
| | **IC3** Decide appropriate method of electrode application | | | | | **63. Patient Cooperation:** Evaluate the patient's level of cooperation and length of recording time and decide appropriate method of electrode application |
| | **IC4** Ascertain the patient's capacity to cooperate with activation procedures | | | | | **64.Contraindications:** Evaluate possible contraindications & patient's ability to cooperate with activation procedures |
| | **IC7** Determine the need for additional physiological monitors | **K-26** Artifact monitoring, identification and elimination | | | | **65. Artifacts:** Determine need for additional physiological monitors. Identify and eliminate artifacts if possible, monitor and document if not possible to eliminate. |
| | | **K-43** Neuroimaging and other diagnostic procedures | | | | **66. Neuroimaging:** Recognize neuroimaging and other diagnostic procedures |
| | **IN1** Maintains and improves knowledge and skills by reviewing EEG recordings with physician interpreter on a regular basis | | **1.3 Support to the Profession**<br>**1.3 a** Supervise students in clinical environments<br>**1.3 b** Provide feedback on student performance<br>**1.3 c** Promote the | | | **67. Recognizes responsibility to maintain and improve professional knowledge** through reading journals, textbooks, attending |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | **IN2** Maintains and improves knowledge and skills by reading journal articles<br>**IN3** Maintains and improves knowledge and skills by studying text books related to the field of NDT<br>**IN4** Maintains and improves knowledge and skills by attending continuing education courses in NDT | | profession to the general public and other healthcare professionals<br>**1.3 d** Portray a positive and confident demeanor and appearance in all professional activities<br>**1.4 Professional Competence**<br>**a.** Practice within the limits of personal knowledge and skills<br>**b.** Self-evaluate and develop clear performance goals to enhance professional effectiveness<br>**c.** Undertake continuing professional development<br>**d.** Participate in quality improvement initiatives | | | continuing education courses or participating in online education and spending time reviewing EEG recordings with interpreter. Participate in Education of students. Portray a positive, and confident demeanor and appearance in all professional activities |
| **Clinical Skill Domain 7: Safety, Professionalism & Code of Ethics** | **IA11** Taking appropriate precautions to ensure electrical safety<br>**IB5** Maintain & respect patient confidentiality | **Domain IV T-1** Conduct practice in a manner consistent with the ABRET Code of Ethics, professional standards and national regulations **T-2** Ensure patient safety<br>**K-35** The ABRET Cod e of Ethics<br>**K-19** Infection Control<br>**K-22** MSDS/OSHA standards | **1. Professional Accountability, Standards, Ethics**<br>**a.** Follow regulations as set out by provincial and federal legislation governing the practice of electroneurophysiology technologists<br>**b.** Recognize patient's right to accept or refuge medical services<br>**c.** Provide care in a fair and unbiased manner<br>**d.** Maintain complete and secure records<br>**2.1 Electrical Safety**<br>**a.** Ensure electrical safety<br>**2.2 Occupational Health and Safety** | | | **68. Professional Accountability, Standards and Ethics** Maintain & respect patient confidentiality, completely secure records and safety by:<br>**a.** Adhering to HIPAA, MSDS/OSHA, (US) or other federal and provincial Occupational Health and Safety Regulations of Workers Compensation Act regulations (Canada)<br>**b.** conducting professional practice in a manner consistent |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | **K-36** National safety techniques<br>**K-37** Electrical safety precautions<br>**K-39** Seizure precautions<br>**K-44** Allergies and sensitivities (latex, tape) | **a.** Apply the standards of the Workplace Hazardous Materials Information System (WHMIS) in the handling, use, storage and disposal of materials<br>**b.** Adhere to workplace standards defined in federal and provincial Occupational Health and Safety Regulations of Workers Compensation Act<br>**c.** Apply the standards of federal and provincial health and wellness to prevent contamination of person, equipment and environment<br>**2.3 Emergency/Disaster Plans**<br>**a.** Determine the nature and gravity of an emergency situation and take appropriate action<br>**3.1 Patient Environment**<br>**a.** Administer first aid/basic life support in emergency situations<br>**b.** Perform aseptic or sterile technique as required<br>**c.** Administer cardiopulmonary resuscitation (CPR) according to the standard of CPR-Level C as specified by Heart and Stroke Foundation of Canada | | | with ABRET Code of Ethics, provide care in a fair and unbiased manner<br>**c.** observing national and state regulations or federal or provincial legislative regulations<br>**d.** maintaining infection control protocols set by CDC, hospital or clinical policies and procedures and lab protocols<br>**e.** observing electrical safety precautions<br>**f.** observing seizure precautions & protocols<br>**g.** asking patient or caregiver about patient's allergies or sensitivities (Latex, tape, etc.)<br>**h.** recognize patient's right to refuse |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | **d.** Perform procedures in a manner that maintains the integrity of patient ancillary devices and equipment<br>**e.** Regulate flow rate of portable and wall-mount oxygen supplies<br>**f.** Apply body-fluid precautions to prevent contamination of person(s), equipment and environment<br>**g.** Ensure a safe and comfortable environment for the patient<br>**h.** Transfer patient safely<br>**i.** Perform procedures in a manner that enhances patient comfort | | | |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | | **69. Emergency/Disaster Plans** a Determine the nature and gravity of an emergency situation and take appropriate action **70. Patient Environment** **a** Administer first aid/basic life support in emergency situations **b** Perform aseptic or sterile technique as required **c** Administer cardiopulmonary resuscitation (CPR) according to the standard of CPR-Level C as specified by the American Heart Association (US) or Heart and Stroke Foundation of Canada **d** Perform procedures in a manner that maintains the integrity of patient ancillary devices and equipment **e** Regulate flow rate of portable and wall-mount oxygen supplies **f** Apply body-fluid precautions to prevent contamination of person(s), equipment and environment |

| Domains of Competence | CoA-NDT U.S. Graduate Competencies | ABRET U.S. Practice Analysis | CAET Canadian Competency Profile | Australian Competencies | U.K. National Exam Standards & Core Criteria | Combined competencies |
|---|---|---|---|---|---|---|
| | | | | | | **g** Ensure a safe and comfortable environment for the patient<br>**h** Transfer patient safely **i** Perform procedures in a manner that enhances patient comfort |

# Appendix B: Combined Competencies with Delphi Statements

I developed Delphi statements using a combination of U.S. (ABRET, n.d.; CoA-NDT, 2012), Australian (ANTA, 2016), Canadian (CAET, 2011), and U.K. (ANS, 2014) instruments.

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| **Clinical Skill Domain 1: Patient Preparation, Interaction, Communication & Teamwork** | **1.Preparation**<br>**a.** Verify patient identify<br>**b.** Verify the procedure is ordered<br>**c.** Examine information on the order for required information and address inconsistencies<br>**d.** Prepare consumables appropriately<br>**e.** Prepare environment according to regulations<br>**f.** Obtain appropriate patient consent<br>**g.** Identify sufficient recording space for recording<br>**h**. When needed transport patient or | **1. Verification of patient identity can be addressed in asynchronous online education.**<br><br>**2. Verification of physician order can be addressed in asynchronous online education.**<br><br>**3. Verification of patient information can be addressed in asynchronous online education.**<br><br>**4. Preparation of EEG lab for patient testing can be addressed in asynchronous online education.**<br><br>**5. Portable bedside EEG preparation can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | instrument to the bedside | |
| | **2. Establish patient rapport** **a.** Introduce self and others present to patient and family and explain professional role **b.** Put patient at ease **c.** Achieve patient | **6. Establishing patient rapport can be addressed using story-based online learning modules.** |

| **Domains of Competence** | **Combined competencies** | **Statements** |
|---|---|---|
| | cooperation<br>**d.** Encourage patient to respond to questions<br>**e.** Make needed and appropriate accommodations for infants and children | |
| | **3. Patient Care: Explain Procedures**<br>**a.** Explain procedure including activation procedures and electrode application<br>**b.** Respond to patient's family/representative within the parameters of patient confidentiality<br>**c.** Refer patient concerns to other healthcare providers as appropriate<br>**4. Patient Instructions** | **7. Explaining the EEG procedure to the patient in a manor appropriate to patient's age can be addressed using story-based learning modules.**<br><br>**8. Explaining the EEG procedure to the patient in a manor appropriate to patient's culture can be addressed using story-based learning modules**<br><br>**9. Explaining the EEG procedure to the patient in a manor appropriate to patient's cognitive abilities can be addressed using story-based learning modules**<br><br>**10. Responding to patient and family's questions can be addressed in asynchronous online education.**<br><br>**11. Making appropriate referrals to other healthcare professionals when needed can be addressed in scenario-based learning modules.**<br><br>**12. Explaining procedure for acquiring test results can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | **a.** Interact on an appropriate level to patient's age, culture and cognitive ability **b.** Provide sufficient pre-test information **c.** Gain sufficient pre-test information **d.** Explain the procedure including answering questions e. Inform patient on procedure to obtain test results | |
| | **5. Teamwork and interprofessional collaboration:** **a.** Interact effectively as a member for a multidisciplinary healthcare team **b.** Distinguish between the scopes of practice of healthcare team members **c.** Demonstrate | **13. Respectful interprofessional collaboration and teamwork can be addressed in interactive simulation online.** <br><br> **14. The scope of practice of other allied healthcare professionals can be addressed in asynchronous online education.** <br><br> **15. Managing workload and productivity skills can be addressed in asynchronous online education.** <br><br> **16. Written and oral communication skills can be addressed in asynchronous online education.** <br><br> **17. Medical terminology can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | respect for a diversity of opinions and values<br>**d.** Manage personal workload to contribute to team productivity **e.** Communicate effectively both orally and in writing<br>**f.** Utilize medical terminology in professional communication<br>**g.** Apply basic problem-solving and conflict resolution techniques<br>**h.** Provide constructive feedback to colleagues | **18. Basic problem-solving can be addressed in problem-based learning online.**<br><br>**19. Conflict resolution techniques can be addressed in interactive simulations.** |
| **Clinical Skill Domain 2: History Taking** | **6. Patient History**<br>**a.** Determine if activation procedures are contraindicated<br>**b.** Take a patient history gathering information from a | **20. Activation procedure contraindication determination can be addressed in asynchronous online education.** |
| | | **21. History taking skills can be addressed in asynchronous online education.**<br><br>**Patient history includes:**<br>**1.** full name |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | chart if available, and by interviewing the patient or caregiver.<br>**c.** Obtain patient information including:<br>**1.** full name<br>**2.** age<br>**3.** hospital or clinic ID number<br>**4.** current symptoms or complaints and indication for the test<br>**5.** referring physician & family physician<br>**6.** recording time<br>**7.** date<br>**8.** technologist's name or initials<br>**9.** any allergies or sensitivities | **2.** age<br>**3.** hospital or clinic ID number<br>**4.** current symptoms or complaints and indication for the test<br>**5.** referring physician & family physician<br>**6.** recording time<br>**7.** date<br>**8.** technologist's name or initials<br>**9.** any allergies or sensitivities<br>**10.** additional information as needed |
| | **7. Document Management:**<br>**a.** Maintain comprehensive records<br>**b.** Document patient history and | **22. EEG data management can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | plan recording strategy to avoid adverse side effects using information from patient record (chart) and information from family or caregivers<br>**c.** Maintain patient confidentiality and privacy<br>**d.** Document a technical description of the recording | |
| | **8. Medications**<br>Document a list of current medications and time of last dosage. | **23. Documentation of medications can be addressed in asynchronous online education.** |
| | **9. Document time of last meal.** | **24. Documentation of time of last meal can be addressed in asynchronous online education.** |
| | **10. Last Seizure**<br>If patient is suspected of seizure, document aura & circumstances of last seizure or symptoms | **25. Documentation of time of last seizure or symptom can be addressed in asynchronous online education.** |
| | **11. Patient State** | **26. Evaluation of patient state can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | Document patient's state, mental, behavioral & level of consciousness (e.g. alert, bright, cooperative, confused, disoriented, comatose, uncooperative, combative, unresponsive, obtunded, etc.) and accommodate for disabilities and special needs | **27. Documentation of patient's state can be addressed in asynchronous online education.** |
| | **12. Skull Condition** Document any skull defects or anomalies | **28. Documentation of skull defects or anomalies can be addressed in asynchronous online education.** |
| | **13. Modifications to the 10-20 System** If modifications of the 10-20 System, diagram changes on the recording for the interpreter | **29. Recognition of the need to make modifications to the 10-20 System can be addressed in asynchronous online education.**<br><br>**30. Documentation of modifications to the 10-20 System can be addressed in asynchronous online education.** |
| **Clinical Skill Domain 3:Practical Underlying** | **14. Patient Safety** Take appropriate precautions to ensure electrical | **31. Patient electrical safety practices can be addressed in asynchronous online education.** |

| **Domains of Competence** | **Combined competencies** | **Statements** |
|---|---|---|
| **Science Knowledge** | safety and patient safety during the EEG recording | |
| | **15. Digital instrumentation** Identify, explain and describe appropriate use of the following:<br>**a.** differential amplifier<br>**b.** polarity & localization<br>**c.** common mode rejection<br>**d.** filters and use<br>**e.** sensitivity<br>**f.** display gain<br>**g.** time-base<br>**h.** reformatting montages<br>**i.** sampling rate<br>**j.** calibration<br>**k.** impedance low & balanced *(below 5K Ohms)*<br>**l.** video monitoring<br>**m.** post-acquisition review (re-formatting montages)<br>**n.** frequency<br>**o.** duration | **32. Digital neurodiagnostic instrumentation can be addressed in asynchronous online education.**<br><br>**33. Application of digital instrumentation concepts can be addressed with problem-based learning online.**<br><br>**34. The role of a system reference in the reformatting of recorded digital EEG data can be addressed in asynchronous online education.**<br><br>**35. Use of montages can be addressed in asynchronous online education.**<br><br>**36. Polarity can be addressed in asynchronous online education.**<br><br>**37. Localization can be addressed in problem-based learning online modules online.**<br><br>**38. Calculation of voltages can be addressed in problem-based learning modules online.**<br><br>**39. Analog to digital conversion can be addressed in problem-based learning modules online.**<br><br>**40. Impact of electrode materials or length can be addressed in asynchronous online education.**<br><br>**41. The integration of video monitoring with EEG recording can be addressed in asynchronous online education.**<br><br>**42. Basic equipment maintenance can be addressed in asynchronous online education.**<br><br>**43. Use of equipment software can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | calculations<br>**p.** voltage calculations<br>**q.** montages<br>**r.** electrode types, impact on recorded potentials and maintenance<br>**s.** electrode material composition and impact on recorded potentials<br>**t.** verifies and documents that the equipment is in good working condition<br>**ma**lfunctioning equipment<br>**v.** manage operation of equipment software<br>**w.** perform routine recording procedures<br>**x.** analog to digital conversion, dwell time and sampling rate<br>**16. Re-formatting Digitally Recorded EEG** | **44. Procedure for documenting system maintenance can be addressed on asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | **Data**<br>**a.** explain how re-formatting of EEG data after the recording is possible<br>**b.** explain role of system reference in reformatting data | |
| | **17. General medical terminology**<br>**18. Neurodiagnostic terminology** | **45. Neurodiagnostic terminology can be addressed in asynchronous online education with audio/video recordings.**<br><br>*** Medical Terminology see #17** |
| | **18. Recognize Normal EEG Patterns:** Normal, awake and sleep, adult, and pediatric EEG patterns<br>**19. Identify EEG Clinical Correlates:** Electrographic correlates to clinical entities<br>**20. Identify Abnormal EEG patterns** in neurological disorders, seizures, | **46. Recognition of normal and normal variant EEG patterns can be addressed in asynchronous online education.**<br><br>**47. Identification of EEG abnormal patterns with clinical correlates can be addressed in case-based learning modules online.** |

| **Domains of Competence** | **Combined competencies** | **Statements** |
|---|---|---|
| | vascular disorders, and brain injury | |
| | **21**. **Neuroanatomy:** Recognize and identify major anatomical structures and function of the major brain regions<br>**22. Neurophysiology** Recognize and Identify the physiological basis of EEG waveforms | **48. Neuroanatomy can be addressed in asynchronous online education.**<br><br>**49. Neurophysiology can be addressed in asynchronous online education.** |
| | **23. Metric System** (US only) | **50. The metric system can be addressed in asynchronous online education.** |
| | **24. Medication effects** on EEG background and waveforms | **51. Medication effects on EEG data can be addressed in asynchronous online education.** |
| | **25. Signs, Symptoms and EEG Correlates to Adult and Pediatric Neurological Disorders:**<br>**a.** seizures<br>**b.** tumors<br>**c.** vascular disease<br>**d.** toxic/metabolic | **52. EEG correlates to adult neurological disorders can be addressed in case-based learning modules online.**<br><br>**53. EEG correlates to pediatric neurological disorders can be addressed in case-based learning modules online.** |

| **Domains of Competence** | **Combined competencies** | **Statements** |
|---|---|---|
| | & infectious diseases | |
| | **26. Psychiatric & psychological disorders** Recognize psychological disorders identified in patient history and physical | **54. Recognition of psychological (psychiatric) disorders from patient history information can be addressed in case-based learning modules online.** |
| | **27. Head trauma** Recognize EEG patters associated with head trauma. Appropriately place electrodes when patients have suffered a head trauma. | **55. Recognition of EEG patterns associated with head-injury can be addressed in case-based learning modules online.** |
| | **28. EEG in Surgery** Identify the use of EEGs during surgical procedures | **56. Identification of the uses of EEG in surgery can be addressed in scenario-based learning modules online.** |
| **Clinical Skill Domain 4: Recording Strategy, Procedural Steps and Post-Study Steps** | **29. Infection control** Clean electrodes, hard and soft surfaces in the lab according to World Health Organization recommendations, national standards, | **57. Infection control procedures can be addressed in asynchronous online education.**<br><br>**58. National and regional health safety standards can be addressed in asynchronous online education.**<br><br>**59. Universal precautions can be addressed in scenario-based learning modules online.**<br><br>**60. Patient positioning for comfort and safety can be addressed in scenario-based** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | regional standards and hospital or clinic protocols. Use personal protective wearables such as disposable gloves for head measurement, electrode preparation, application, and removal. Use masks and gowns when indicated. Dispose of contaminated materials appropriately. **30. Comply with national and regional safety standards** for staff and materials used in the work environment such as MSDS/OSHA standards (US) to protect employees from hazards or harm. **31. Universal Precautions** | **learning modules online.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | Make use of infection control precautions with all patients.<br>**32. Comply with lab protocols**, **policies and procedures** while preparing the physical area for the patient<br>**a.** Prepare and clean electrodes<br>**b.** Store electrodes properly<br>**33. Position patient** safely allowing for adequate accessibility, relaxed state and patient comfort | |
| | **34. Emergencies:** Recognize and respond to life threatening situations including maintaining a CPR credential | **61. Recognition of emergency situations can be addressed in scenario-based learning online.**<br><br>**62. Appropriate responses to emergency situations can be addressed in scenario-based learning modules online.** |
| | **35. Sedation:** Follow lab protocols on sedation | **63. Compliance with sedation protocols can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | **36. Disaster and emergency:** Be aware of and comply with lab protocols for emergency & disaster situations plans | **64. Disaster and emergency protocols can be addressed in scenario-based learning modules online.** |
| | **37. Fundamental Equipment Maintenance** **a.** Perform routine cleaning, system checks, minor repairs & maintenance of equipment. **b.** Schedule periodic maintenance & document regular electrical safety checks | **65. Fundamental NDT equipment maintenance can be addressed in problem-based learning modules online.** |
| | **38. Electrode Application:** Measure and apply electrodes using the International 10-20 System of Electrode Placement or 10-10 System, T1, T2, system reference | **66. Electrode application using the International 10-20 System of electrode placement can be addressed in asynchronous online education with video demonstration, video assignments and video assessments.**<br><br>**67. Placement of monitoring electrodes can be addressed in asynchronous online education with video demonstration.**<br><br>**68. Monitoring ECG/EKG can be addressed in asynchronous online education.**<br><br>**69. The importance of good electrode placement and the consequences of poor** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | electrode, ground/common electrode, EOG, ECG/EKG, EMG and additional electrodes as needed, with a margin of error of less than 1 cm per chain of electrode placements.<br>**a.** Monitors ECG/EKG routinely and respiration, EMG or other artifacts when needed.<br>**b.** Explain the importance of good electrode placement and the consequences of inaccurate electrode measurement and placement<br>**c.** Identify advantages and disadvantages of different types of application – surface electrodes with | **placement can be addressed in asynchronous online education.**<br><br>**70. Advantages and disadvantages of different types of electrodes application methods can be addressed in asynchronous online education.**<br><br>**71. 10-20 measurement techniques can be assessed using video assignments and assessments.**<br><br>**72. Electrode application techniques can be assessed using video assignments.**<br><br>**73. Preparation of electrode sites for electrode application can be addressed in asynchronous online education with video demonstration.**<br><br>**74. Importance of low and balanced impedances can be addressed in asynchronous online education.**<br><br>**75. Importance of stable electrode placement for lengthy recordings can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | paste, surface electrodes with Collodion, sub-dermal needle electrodes.<br>**d.** Demonstrate appropriate stability of electrode application for the length of recording<br>**39. Prepare electrode sites** to reduce impedance<br>**40. Securely applies electrodes** with collodion or paste method<br>**41. Checks impedance** to ensure electrode integrity | |
| | **42. 10-20 Modifications** Adjust or modify 10-20 System placements to accommodate for skull defects or anomalies | **76. Appropriate modifications of the 10-20 System to expand recording or make accommodations for skull defects or bandaging can be addressed in asynchronous online education.** |
| | **43.** Applies | **77. Different techniques of electrode application can be addressed in asynchronous** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | electrodes *appropriately* using paste or collodion | **online education with video demonstration.** |
| | **44. Standards:** Performs EEG study according to standards set by national agencies or physician or technologist/scientist organizations in clinical neurophysiology such as the ACNS in the US or your national Standards and Guidelines<br>**a.** make use of montages as needed including routine referential and bipolar montages and common average reference montages, Laplacian source derivation or modified montages as needed to enhance abnormalities.<br>**b.** use calibration | **78. National or International standards in the performance of EEG can be addressed in asynchronous online education.**<br><br>**79. Montage use can be addressed in asynchronous online education with illustrations (EEG samples).**<br><br>**80. Appropriate instrument calibration can be addressed in asynchronous online education.**<br><br>**81. The importance of EEG recording length in the acquisition of sleep can be addressed in asynchronous online education.**<br><br>**82. The use of activation procedures can be addressed in asynchronous online education.**<br><br>**83. The importance of annotations on the EEG recording can be addressed in asynchronous online education.**<br><br>**84. A common list of annotations to be programed into digital EEG instruments can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | when available or alternative system check to verify system integrity<br>**c.** record long enough to ensure the patient has an opportunity to achieve light sleep<br>**d.** make use of video and audio recording of patient during EEG if available<br>**e.** use sleep deprivation when appropriate<br>**45. Administration of activation procedures** of hyperventilation (when not contraindicated), photic stimulation, eye opening & closing & encouraging sleep when possible<br>**46. Annotations:** Makes notations of patient sedation if given, instrument | |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | settings if not automatically noted and observed behaviors, symptoms, movements, artifacts, clinical seizure manifestations, and level of consciousness throughout the recording, especially clinically significant behaviors. Annotate instrument settings if not automatically noted on recording | |
| | **47. Recording Strategy:** Follow technical criteria for recording and modify or adjust the recording strategy and/or instrument parameters based on the technologist's evaluation of | **85. Design of an EEG recording strategy can be addressed in case-based learning modules online.**<br><br>**86. Recording procedures for suspected electrocerebral inactivity (ECI) formerly called electrocerebral silence (ECS) can be addressed in asynchronous online education.**<br><br>**87. Recording procedures for suspected electrocerebral inactivity (ECI) formerly called electrocerebral silence (ECS) can be enhanced using case-based learning modules online.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | recorded data to ensure a complete, comprehensive and technically satisfactory study, adapting the study based on the patient’s age, status and condition: **a.** Neonatal **b.** Pediatric **c.** ICU patients **d.** Injury resulting in burns or trauma **e**. Perform visual, auditory, somatosensory and painful stimulation reactivity tests for patients with impaired levels of consciousness f. Adapt procedures during the recording as required **g.** Respond to and document patient seizures **48. Electrocerebral Inactivity: a.** Perform suspected | |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | electrocerebral silence (electrocerebral inactivity) ECS/ECI studies according to specifications set by ACNS (US) or national organization of clinical neurophysiology | |
| | **49.** Remove electrodes, clean electrode sites removing paste/collodion from patient's hair and scalp. Clean and disinfect electrodes before use according to World Health Organization recommendations and hospital or clinic protocols. | **88. Electrode removal procedures can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | **50.** Follows policies, procedures, MSDS/OSHA and HIPAA standards | **89. Appropriate attention to Medical Safety Data Sheets (MSDS) can be addressed in asynchronous online education.**<br><br>**90. Occupational Safety and Health Administration (OSHA) regulations can be addressed in asynchronous online education.**<br><br>**91. Compliance with the Health Insurance Portability and Accountability Act (HIPAA) can be addressed in asynchronous online education.** |
| | **51.** Process acquired data, and manage media (spike-detection software, copy, storage, archive, etc.) | **92. Processing EEG data can be addressed in asynchronous online education.**<br><br>**93. Managing EEG data can be addressed in asynchronous online education.**<br><br>**94. Application of spike-detection software can be addressed in asynchronous online education with illustrations of data or video demonstrations.** |
| | **52.** Customizes recording to address specific patient needs and age-specific criteria including neonatal, pediatric, intensive care and cardiac care patients. | **95. Customization of recording strategy to address needs of patients can be addressed in case-based learning modules online.** |
| **Clinical Skill Domain 5: Observational Skills and Situational Awareness** | **53. Observes patient during recording** and appropriately attends to needs including the special needs of physically or | **96. Appropriate observation of patients during the EEG recording can be addressed in case-based learning modules online.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | mentally handicapped patients. | |
| | **54. Analyze EEG Data: a.** Apply polarity convention, knowledge of montages to localize EEG activity **b.** Observe EEG data and correlates patterns with age specific developmental criteria, clinical correlates, and recognizes normal, normal variant, and abnormal EEG patterns with clinical correlates **c.** When needed the technologist relates observed patterns to the interpreting physician for his/her immediate attention **d.** monitor patient state, sleep, and movements | **97. Application of polarity convention to localize EEG activity can be addressed in problem-based learning modules online.**<br><br>**98. Recognition of developmental patterns in EEG data can be addressed in asynchronous online education that is rich in illustrations of EEG.**<br><br>**99. Recognition of developmental patterns in EEG data can be enhanced using case-based online modules.**<br><br>**100. Patterns requiring immediate attention of the interpreting neurologist can be addressed in case-based learning modules online.**<br><br>**101. Recognition of changes in the patient's state can be addressed in asynchronous online.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | **55. Emergencies:** Recognizes and responds to life threatening situations | **102. Recognition of life-threatening conditions can be addressed in case-based learning modules online.** |
| | **56. Artifacts:** Identifies recognizes & differentiates artifact from cerebral waveforms, documents, monitors or eliminates as appropriate | **103. Artifact recognition, monitoring or elimination techniques can be addressed in asynchronous online education.**<br><br>**104. Artifact recognition, monitoring or elimination techniques can be enhanced with scenario-based modules online.** |
| | **57. Electrocardiogram rhythm channel:** Routinely applies and monitors ECG/EKG | **105. Recognition of ECG/EKG rhythm abnormalities can be addressed in asynchronous online education and case-based learning modules online.** |
| | **58. Electrode integrity:** Replaces electrodes exhibiting questionable activity, poor impedance or poor contact with the scalp or appears to be broken | **106. Recognition of electrodes of questionable integrity needing reapplication or replacement can be addressed in asynchronous online education with illustrations (EEG samples).** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | **59. Troubleshooting:** Troubleshoots for possible electrical interference or 60 Hz noise | **107. Troubleshooting for sources of 60 or 50 Hz noise in the EEG data can be addressed in asynchronous online education.**<br><br>**108. Troubleshooting for sources of 60 or 50 Hz noise in the EEG data can be enhanced with scenario-based learning modules online.** |
| | **60. Submit recording for review** | **109. Appropriate submission of EEG recording data can be addressed in asynchronous online education.** |
| **Clinical Skill Domain 6: Clinical Reasoning/Problem-Solving & Critical Thinking** | **61. Assesses patient, appropriately**<br>**a.** attends to patient needs including special needs associated with physical or mental handicap<br>**b.** Identify the need and demonstrate the testing of the patient's responsiveness and memory during suspected clinical and electrographic seizures<br>**c.** Recognize and respond when assistance is required including:<br>1. behavioral difficulties | **110. Appropriate patient assessment before and during the EEG recording can be addressed in asynchronous online education.**<br><br>**111. Appropriate patient assessment before and during the EEG recording can be enhanced with case-based learning modules online.**<br><br>**112. Recognition of patients needing special assistance can be addressed in asynchronous online education.**<br><br>**113. Appropriately responding to patients needing special assistance can be addressed in scenario-based learning modules online.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | 2. clinical seizure<br>3. clinical state<br>4. ECG/EKG abnormalities<br>5. other medical emergencies | |
| | **62. Recognize significant patient behaviors and clinical events** including life threatening situations and responds appropriately | **114. Recognition of clinical or behavioral events of significance can be addressed in asynchronous online education and case-based learning modules online.**<br><br>**115. Appropriate responses to clinical or behavioral events of significance can be addressed using case-based learning modules online.** |
| | **63. Patient Cooperation:** Evaluate the patient's level of cooperation and length of recording time and decide appropriate method of electrode application | **116. Evaluation of the patient's level of cooperation and correlation with appropriate method of electrode application can be addressed in asynchronous online education.** |
| | **64.Contraindications:** Evaluate possible contraindications & patient's ability to cooperate with activation procedures | **117. Coordination of the patient's ability to cooperate with activation procedures can be addressed in asynchronous online education.**<br><br>**118. Contraindications for activation procedures can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | **65. Artifacts:** Determine need for additional physiological monitors. Identify and eliminate artifacts if possible, monitor and document if not possible to eliminate. | **119. The identification of artifacts can be addressed in asynchronous online.**<br><br>**120. Monitoring procedures for artifacts that cannot be eliminated can be addressed in scenario-based learning modules online.** |
| | **66. Neuroimaging:** Recognize neuroimaging and other diagnostic procedures | **121. Recognition of other diagnostic procedures such as neuroimaging can be addressed in asynchronous online education.** |
| | **67. Recognizes responsibility to maintain and improve professional knowledge** through reading journals, textbooks, attending continuing education courses or participating in online education and spending time reviewing EEG recordings with | **122. The responsibility of healthcare professionals to continually maintain and improve professional knowledge can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | interpreter. Participate in Education of students. Portray a positive, and confident demeanor and appearance in all professional activities | |
| **Clinical Skill Domain 7: Safety, Professionalism & Code of Ethics** | **68. Professional Accountability, Standards and Ethics** Maintain & respect patient confidentiality, complete secure records and safety by: **a.** Adhering to HIPAA, MSDS/OSHA, (US) or other federal and provincial Occupational Health and Safety Regulations of Workers Compensation Act regulations (Canada) | **123. Professional accountability as established through standards and ethics (according to national or international standards) can be addressed in asynchronous online education. (See also 78)**<br><br>**124. Professional accountability as established through standards and ethics (according to national or international standards) can be enhanced using scenario-based modules online. (See also 78)**<br><br>**125. Observation of international, national, state, provincial or other applicable regulations or legislation can be addressed in asynchronous online education.**<br><br>**126. Infection control practices according to national or international standards can be addressed in asynchronous online education.**<br><br>**127. Observation of electrical safety standards and regulations can be addressed in asynchronous online education.**<br><br>**128. Observation of appropriate seizure precaution can be addressed with asynchronous online education with video demonstration.**<br><br>**129. Seizure First Aid can be addressed with asynchronous online education with video demonstration.** |

| Domains of Competence | Combined competencies | Statements |
| --- | --- | --- |
| | **b.** conducting professional practice in a manner consistent with ABRET Code of Ethics, provide care in a fair and unbiased manner<br>**c.** observing national and state regulations or federal or provincial legislative regulations<br>**d.** maintaining infection control protocols set by CDC, hospital or clinical policies and procedures and lab protocols<br>**e.** observing electrical safety precautions<br>**f.** observing seizure precautions & protocols<br>**g.** asking patient or caregiver about patient's allergies or sensitivities (Latex, tape, etc.) | **130. Recognition of the patient's right to refuse testing can be addressed in asynchronous online education.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | **h.** recognizes patient's right to refuse | |
| | **69. Emergency/Disaster Plans**<br>a Determine the nature and gravity of an emergency situation and take appropriate action<br>**70. Patient Environment**<br>a Administer first aid/basic life support in emergency situations<br>b Perform aseptic or sterile technique as required<br>c Administer cardiopulmonary resuscitation (CPR) according to the standard of CPR-Level C as specified by the American Heart Association (US) or Heart and Stroke Foundation of Canada (Canada) | **131. Training for emergency or disaster situations can be addressed in video demonstration online and is usually specialized to the facility and required for employment so usually provided in the workplace.**<br><br>**132. Cardiopulmonary Resuscitation is generally an outsourced training provided by employers to healthcare professionals either onsite or nearby and involves demonstration and the use of a simulation mannequin.**<br><br>**133. Situational awareness of ancillary equipment around the patient can be addressed in asynchronous online education.**<br><br>**134. Regulation of the flow of oxygen for patients needing oxygen while an EEG study is performed can be addressed in scenario-based learning modules online.**<br><br>**135. Providing a safe patient environment for the EEG recording can be addressed in scenario-based learning modules online.**<br><br>**136. Providing a comfortable patient environment for the EEG recording can be addressed in scenario-based learning modules online.**<br><br>**137. Transferring patients safely into and out of a gurney, wheelchair, bed or when using a walker or other aid to walking can be addressed using online education with video demonstrations.**<br><br>**138. The need for informed consent documentation can be addressed in asynchronous online learning.** |

| Domains of Competence | Combined competencies | Statements |
|---|---|---|
| | d Perform procedures in a manner that maintains the integrity of patient ancillary devices and equipment<br>e Regulate flow rate of portable and wall-mount oxygen supplies<br>f Apply body-fluid precautions to prevent contamination of person(s), equipment and environment<br>g Ensure a safe and comfortable environment for the patient<br>h Transfer patient safely i Perform procedures in a manner that enhances patient comfort | |

# Appendix C: Invitation to Potential Expert Panelists

Potential educational technology volunteers were recruited from the SimConnect site for the Society for Simulation in Healthcare, the International Society for Technology in Education's forums, and the Walden Participant Pool. Volunteers will also include experienced professionals and educators in neurodiagnostic technology (NDT) known through their participation in NDT education. Educational technology panelists will include researchers in educational technology and educational technology professionals recruited through posts to the societies, the participant pool at Walden or email invitation. Excluded are Walden faculty, students not volunteering through the Walden Participant Pool, participants outside the U.S. and administrative staff of the Institutes of Health Science.

Subject: Looking for Educational Technology Experts to Participate in a Delphi Study: Exploring the Use of Educational Technology in Neurodiagnostic Technology Clinical Skill Training

Dear potential participant,

I would like to invite you to participate as a potential member of a Delphi study panel of experts. A Delphi study is a research tool that brings together experts to make projections about unknown future trends or as a tool for consensus building. If you meet the inclusion criteria and agree to participate, your identity will be kept confidential and you will be included in three rounds of a Delphi instrument, taking approximately one hour per week for three weeks. The Delphi instruments contain a list of statements pairing competencies with educational technology methods. You will rate statements on a four-point scale of effectiveness based on your expertise. You will also be given an opportunity to provide new statements. After all the panelists have rated the statements, the responses will be compiled and the results will be shared with the panelists in the second round. For the second and third rounds, the tabulated responses and additional new statements will be shared. You will be expected to actively participate and reply within four days of being asked to evaluate each round of the Delphi instrument.

**Purpose of the Study**

The purpose of the study is to form a consensus about the use of educational technology to provide neurodiagnostic clinical skill training wherever possible in preparing graduates for post-graduate residencies where they would obtain clinical experience before taking credentialing exams. If such a training pathway could be established, the NDT schools would not be limited by the number of clinical sites available, and enrollments could be expanded to better suit the demands of the field.

**Inclusion Criteria**

There will be two groups of experts, those with expertise in educational technology and those with expertise in neurodiagnostic technology. Inclusion criteria for educational technology expert panelists is a minimum of a master's degree in educational technology, instructional design or education with experience in educational technology, or current students in an educational technology Ph.D. program. A background in healthcare education is preferred but not required. Neurodiagnostic panelists will need a minimum of one NDT credential (ABRET registration in either EEG, Evoked Potentials, or certification in CNIM or CLTM) and five years of experience training technologists. Training experience can be in a formal school, continuing education, or on-the-job training. Participants without the specified expertise in either NDT or educational technology will not be included. Participants unwilling to commit the time needed to complete the study will not be included.

In the event that more than 30 participants come forward with appropriate qualifications, the number of participants may be increased with a balance of participants from both fields of expertise. If fewer than 30 participants volunteer to participate, additional efforts will be made to recruit participants. If one field has a greater number of volunteers, a relative balance will be achieved by selecting NDT participants with a greater number of ABRET credentials and educational technology participants with higher levels of education. Educational technology participants with healthcare experience will be given preference over those without healthcare education experience but those without healthcare experience will not be excluded.

**Questions for Potential Participants**

Please provide short answers to the following screening questions to see if you meet the inclusion criteria. Simply reply to this email and type your answers below each question. A Delphi study expert panel is not a randomly selected group. Invited participants must meet certain criteria before selection.

Please reply to this email and answer the questions below. You can copy and paste them or simply reply and insert your answers under each question.

**Contact information**

Full name:

Email:

Phone numbers:

1. Experience with educational technology, online education, or distance education:

Educational experience:

Degrees: Credentials:

Positions held: Years of experience:

2. Experience with neurodiagnostics, medical, nursing, or allied healthcare education:

Healthcare field if not NDT:

Degrees: Credentials:

Positions held: Years of experience:

Thank you for considering participation as an expert-panelist in my Delphi study and dissertation research. If you are interested in participating please reply with your contact information and answers to the questions above and I will send you a consent form.

Sincerely,

Maggie Marsh-Nation

Doctoral Candidate in Educational Technology at Walden University

[address redacted]

Office phone: [redacted]

cell: [redacted] email: [redacted]

# Appendix D: Delphi Instrument 1

I developed Delphi statements using a combination of U.S. (ABRET, n.d.; CoA-NDT, 2012), Australian (ANTA, 2016), Canadian (CAET, 2011), and U.K. (ANS, 2014) competencies.

| | Statement | Rating |
|---|---|---|
| 1 | 1. Verification of patient identity can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 2 | 2. Verification of physician order can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 3 | 3. Verification of patient information can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 4 | 4. Preparation of EEG Lab for patient testing can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 5 | 5. Portable bedside EEG preparation can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 6 | 6. Establishing patient rapport can be addressed using story-based learning modules (Paliadelis et al., 2015; Shaw et al., 2017). | 1, 2, 3, 4 |
| | New statement to add: | |
| 7 | 7. Explaining the EEG procedure in a manor appropriate to patient's age can be addressed using story-based learning modules (Paliadelis et al., 2015; Shaw et al., 2017). | 1, 2, 3, 4 |
| | New statement to add: | |
| 8 | 8. Explaining the EEG procedure in a manor appropriate to patient's culture can be addressed using story-based learning modules (Paliadelis et al., 2015; Shaw et al., 2017). | 1, 2, 3, 4 |
| | New statement to add: | |
| 9 | 9. Explaining the EEG procedure in a manor appropriate to patient's cognitive abilities can be addressed using story-based learning modules (Paliadelis et al., 2015; Shaw et al., 2017). | 1, 2, 3, 4 |
| | New statement to add: | |
| 10 | 10. Responding to patient and family's questions can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 11 | 11. Making appropriate referrals to other healthcare professionals when needed can be addressed in scenario-based learning modules (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 12 | 12. Explaining procedure for acquiring test results can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U. inS. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 13 | 13. Respectful interprofessional collaboration and teamwork can be addressed in interactive simulation online (Bolesta & Chmil, 2014; Institutes of Medicine, 2003; Reime et al., 2016). | 1, 2, 3, 4 |
| | New statement to add: | |
| 14 | 14. The scope of practice of other allied healthcare professionals can be addressed with asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 15 | 15. Managing workload and productivity skills can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 16 | 16. Written and oral communication skills can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 17 | 17. Medical terminology can be addressed in asynchronous online education with audio/video recordings (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |

| | | |
|---|---|---|
| | New statement to add: | |
| 18 | 18. Basic problem-solving can be addressed in problem-based learning online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 19 | 19. Conflict resolution techniques can be addressed in interactive simulations (McPherson & MacDonald, 2017; MacLean et al., 2017; Bolesta & Chmil, 2014; Reime et al., 2016; Mccullough, 2013). | 1, 2, 3, 4 |
| | New statement to add: | |
| 20 | 20. Activation procedure contraindication determination can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 21 | 21. History taking skills can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 22 | 22. EEG data management can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 23 | 23. Documentation of medications can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 24 | 24. Documentation of time of last meal can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 25 | Documentation of time of last seizure or symptom can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 26 | 26. Evaluation of patient state can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 27 | 27. Documentation of patient state can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 28 | 28. Documentation of skull defects or anomalies can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 29 | 29. Recognition of the need to make modifications to the 10-20 System can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 30 | 30. Documentation of modifications to the 10-20 System can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 31 | 31. Patient electrical safety practices can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 32 | 32. Digital neurodiagnostic instrumentation can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 33 | 33. Application of digital instrumentation concepts can be addressed with problem-based learning online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 34 | 34. The role of a system reference in reformatting of recorded digital EEG data can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 35 | 35. Use of montages can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 36 | 36. Polarity can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |

| | | |
|---|---|---|
| 37 | 37. Localization can be addressed with problem-based learning online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 38 | 38. Calculation of voltages can be addressed with problem-based learning online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 39 | 39. Analog to digital conversion can be addressed with problem-based learning online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 40 | 40. Impact of using electrodes of differing materials or length can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 41 | 41. The integration of video monitoring with EEG recording can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 42 | 42. Basic equipment maintenance can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 43 | 43. Use of equipment software can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 44 | 44. Procedure for documenting system maintenance can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 45 | 45. Neurodiagnostic terminology can be addressed in asynchronous online education with audio/video recordings (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 46 | 46. Recognition of normal and normal variants EEG patterns can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 47 | 47. Identification of EEG abnormal patterns with clinical correlates can be addressed in case-based learning modules online (Fortun et al., 2017; Lunney, 2010; MacLean et al., 2017; Raurell-Torredá et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 48 | 48. Neuroanatomy can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 49 | 49. Neurophysiology can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 50 | 50. The metric system can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010) | 1, 2, 3, 4 |
| | New statement to add: | |
| 51 | 51. Medication effects on EEG data can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 52 | 52. EEG correlates to adult neurological disorders can be addressed in case-based learning modules online (Fortun et al., 2017; Lunney, 2010; MacLean et al., 2017; Raurell-Torredá et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 53 | 53. EEG correlates to pediatric neurological disorders can be addressed in case-based learning modules online (Fortun et al., 2017; Lunney, 2010; MacLean et al., 2017; Raurell-Torredá et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 54 | 54. Recognition of psychological (psychiatric) disorders from patient history information can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 55 | 55. Recognition of EEG patterns associated with head injury can be addressed in case-based learning modules online (Fortun et al., 2017; Lunney, 2010; MacLean et al., 2017; Raurell-Torredá et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |

| | | |
|---|---|---|
| 56 | 56. Identification of the uses of EEG in surgery can be addressed in scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 57 | 57. Infection control procedures can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 58 | 58. National and regional health safety standards can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 59 | 59. Universal precautions can be addressed in scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 60 | 60. Patient positioning for comfort and safety can be addressed in scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 61 | 61. Recognition of emergency situations can be addressed in scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 62 | 62. Appropriate responses to emergency situations can be addressed in scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 63 | 63. Compliance with sedation protocols can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 64 | 64. Disaster and emergency protocols can be addressed in scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 65 | 65. Fundamental NDT equipment maintenance can be addressed with problem-based learning online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 66 | 66. Electrode application using the International 10-20 System of electrode placement can be addressed in asynchronous online education with video demonstration, video assignments and video assessments (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 67 | 67. Placement of monitoring electrodes can be addressed in asynchronous online education with video demonstration (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 68 | 68. Monitoring ECG/EKG can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 69 | 69. The importance of good electrode placement and consequences of poor placement can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 70 | 70. Advantages and disadvantages of different types of electrodes application methods can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 71 | 71. International 10-20 Measurement techniques can be assessed using video assignments or assessments (Dy-Bourman et al., 2017; McIntosh et al., 2018; Yeung et al., 2017). | 1, 2, 3, 4 |
| | New statement to add: | |
| 72 | 72. Electrode application techniques can be assessed using video assignments or assessments (Dy-Bourman et al., 2017; McIntosh et al., 2018; Yeung et al., 2017) | 1, 2, 3, 4 |
| | New statement to add: | |
| 73 | 73. Preparation of electrode sites for electrode application can be addressed in asynchronous online education with video demonstration (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 74 | 74. Importance of low and balanced impedances can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |

| | | |
|---|---|---|
| 75 | 75. Importance of stable electrode placement for lengthy EEG recordings can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 76 | 76. Appropriate modifications of the 10-20 System to expand recording or make accommodations for skull defects or bandaging can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 77 | 77. Different techniques of electrode application can be addressed in asynchronous online education with video demonstration (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 78 | 78. National or International standards in performance of EEG can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 79 | 79. Montage use can be addressed in asynchronous online education with illustrations (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 80 | 80. Appropriate instrument calibration can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 81 | 81. The importance of EEG recording length in acquisition of sleep can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 82 | 82. The use of activation procedures can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 83 | 83. The importance of annotations on the EEG recording can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 84 | 84. A common list of annotations to be programmed into the digital EEG instrument can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 85 | 85. Design of an EEG recording strategy can be addressed in case-based learning modules online (Fortun et al., 2017; Lunney, 2010; MacLean et al., 2017; Raurell-Torredá et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 86 | 86. Recording procedures for suspected electrocerebral inactivity (ECI) formerly called electrocerebral silence (ECS) can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 87 | 87. Recording procedures for suspected electrocerebral inactivity (ECI) formerly called electrocerebral silence (ECS) can be enhanced in case-based learning modules online (Fortun et al., 2017; Lunney, 2010; MacLean et al., 2017; Raurell-Torredá et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 88 | 88. Electrode removal procedures can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 89 | 89. Appropriate attention to Medical Safety Data Sheets (MSDS) can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 90 | 90. Occupational Safety and Health Administration (OSHA) regulations can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 91 | 91. Compliance with the Health Insurance Portability and Accountability Act (HIPAA) can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 92 | 92. Processing EEG data can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 93 | 93. Managing EEG data can be addressed in asynchronous online education (Rivkin, 2016; | 1, 2, 3, 4 |

| | | |
|---|---|---|
| | Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | |
| | New statement to add: | |
| 94 | 94. Application of spike-detection software can be addressed in asynchronous online education with illustrations of data and video demonstration (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 95 | 95. Customization of recording strategy to address needs of patients can be addressed in case-based learning modules online (Fortun et al., 2017; Lunney, 2010; MacLean et al., 2017; Raurell-Torredá et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 96 | 96. Appropriate observation of patients during the EEG recording can be addressed in case-based learning modules online (Fortun et al., 2017; Lunney, 2010; MacLean et al., 2017; Raurell-Torredá et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 97 | 97. Application of polarity convention to localize EEG activity can be addressed with problem-based learning online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 98 | 98. Recognition of developmental patterns in EEG data can be addressed in asynchronous online education rich in illustrations of EEG data samples (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 99 | 99. Recognition of developmental patterns in EEG data can be enhanced using case-based learning modules online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 100 | 100. Patterns requiring immediate attention of the interpreting neurologist can be addressed in case-based learning modules online (Fortun et al., 2017; Lunney, 2010; MacLean et al., 2017; Raurell-Torredá et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 101 | 101. Recognition of changes in the patient's state can be addressed in asynchronous online education rich in illustrations of EEG data samples (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 102 | 102. Recognition of life-threatening conditions can be addressed in case-based learning modules online (Fortun et al., 2017; Lunney, 2010; MacLean et al., 2017; Raurell-Torredá et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 103 | 103. Artifact recognition, monitoring or elimination techniques can be addressed using case-based learning modules online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 104 | 104. Artifact recognition, monitoring or elimination techniques can be enhanced using case-based learning modules online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 105 | 105. Recognition of ECG/EKG rhythm abnormalities can be addressed in asynchronous online education rich in illustrations and samples (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 106 | 106. Recognition of electrodes of questionable integrity needing reapplication or replacement can be addressed in asynchronous online education rich in illustrations and samples (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 107 | 107. Troubleshooting for sources of 60 or 50 Hz noise in the EEG data can be addressed in asynchronous online education rich in illustrations of EEG data samples (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 108 | 108. Troubleshooting for sources of 60 or 50 Hz noise in the EEG data can be enhanced using scenario-based online learning modules (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 109 | 109. Appropriate submission of EEG recording data can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |

| | | |
|---|---|---|
| 110 | 110. Appropriate patient assessment before and during the EEG recording can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 111 | 111. Appropriate patient assessment before and during the EEG recording can be enhanced using case-based learning modules online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 112 | 112. Recognition of patients needing special assistance can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 113 | 113. Appropriately responding to patients needing special assistance addressed using scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 114 | 114. Recognition of clinical or behavioral events of significance can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 115 | 115. Appropriate responses to clinical or behavioral events of significance can be addressed using case-based learning modules online (Wyles et al., 2013; Landed et al., 2016; Too & Park, 2014; Ellaway et al., 2015; Nevin et al., 2014, McLean et al., 2014). | 1, 2, 3, 4 |
| | New statement to add: | |
| 116 | 116. Evaluation of the patient's level of cooperation and correlation with appropriate method of electrode application can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 117 | 117. Coordination of patient's ability to cooperate with activation procedures can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 118 | 118. Contraindications for activation procedures can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 119 | 119. The identification of artifacts can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 120 | 120. Monitoring procedures for artifacts that cannot be eliminated can be addressed in scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 121 | 121. Recognition other diagnostic procedures such as neuroimaging can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 122 | 122. The responsibility of healthcare professionals to continually maintain and improve professional knowledge can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 123 | 123. Professional accountability as established through standards and ethics (according to national or international standards) can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 124 | 124. Professional accountability as established through standards and ethics (according to national or international standards) can be enhanced using scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 125 | 125. Observation of international, national, state, provincial and other applicable regulations or legislation can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 126 | 126. Infection control practices according to national or international standards can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 127 | 127. Observation of electrical safety standards and regulations can be addressed in asynchronous | 1, 2, 3, 4 |

| | | |
|---|---|---|
| | online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | |
| | New statement to add: | |
| 128 | 128. Observation of appropriate seizure precautions can be addressed in asynchronous online education with video demonstrations (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 129 | 129. Seizure First Aid can be addressed in asynchronous online education with video demonstration (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 130 | 130. Recognition of a patient’s right to refuse testing can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 131 | 131. Training for emergency or disaster situations can be addressed in asynchronous online education with video demonstrations and is usually specialized to the facility and required for employment, so usually provided in the workplace (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 132 | 132. Cardiopulmonary Resuscitation is generally an outsourced training provided by employers to healthcare professionals either onsite or nearby and involves demonstration and use of simulation mannequin. (Tolsgaard et al., 2015; Kwant et al., 2015; Cummings & Connelly, 2016; Gruenke et al., 2016; Woda et al., 2016; Keskitalo & Ruokamo, 2016). | 1, 2, 3, 4 |
| | New statement to add: | |
| 133 | 133. Situational awareness of ancillary equipment around the patient can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 134 | 134. Regulation of the flow of oxygen for patients needing oxygen while an EEG study is performed can be addressed in scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 135 | 135. Providing a safe environment for the patient during EEG recording can be addressed in scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 136 | 136. Providing a comfortable environment for the patient during EEG recording can be addressed in scenario-based learning modules online (Persson et al., 2014; Weston, 2015). | 1, 2, 3, 4 |
| | New statement to add: | |
| 137 | 137. Transferring patients safely into or out of a gurney, wheelchair, bed or walker can be addressed in asynchronous online education with video demonstration (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |
| 138 | 138. The need for informed consent documentation can be addressed in asynchronous online education (Rivkin, 2016; Shellenbarger & Robb, 2015; U.S. Department of Education, 2010). | 1, 2, 3, 4 |
| | New statement to add: | |

Appendix E: Permission to Invite Panelists

**From:** Margaret Marsh-Nation
**Date:** Monday, May 7, 2018 at 4:17 PM
**To:** Ashley Grossman <agrossman@ssih.org>, SSH Admin <admin@ssih.org>
**Subject:** Permission to invite via the SSH forums participants for a study for my dissertation

Good afternoon,

My name is Maggie Marsh-Nation and I am a doctoral candidate at Walden University. I am doing a dissertation titled "Exploring the Use of Educational Technology in Neurodiagnostic Clinical Skills". I need to enlist the help of 15 experts in educational technology with at least a master's in education and experience in educational technology. If they have healthcare experience as well, all the better. They will participate in a Delphi study along with 15 experts in neurodiagnostic technology.

The study will take approximately one hour per week for three weeks. The identity of the participants will not be published or known to the other expert panel members. The names of participants will be known only to me and my dissertation committee. The only information about the expert panel that will be shared is the collective degrees, certifications and years of experience for the group in total. (example: 5 PhDs in Educational Technology, 4 Masters in Instructional Design, etc.)

I have seen other postings requesting participants to take part in studies. In filling out my IRB forms I need written permission (email) from the society. There will no reimbursement or gift. It will be completely volunteer.

Thank you for your help. I'd love a quick response as it is nearing the end of the quarter and I'd like to submit the IRB so I can finish up next quarter.

Have a wonderful week. You can contact me at the numbers below. Try the voice number first as I live on the edge of town and my cell works well only when I leave home.

Thanks again,
Maggie

Maggie Marsh-Nation

Doctoral Candidate in Educational Technology at Walden Univ.
[address redacted]
office phone: [redacted], cell: [redacted] fax: [redacted]

From: admin@ssih.org
Re: Permission to invite via the SSH forums participants for a study for my dissertation

To: Margaret Marsh-Nation
Cc: Kathy Adams Ashley Grossman
From: admin@ssih.org, kadams@ssih.org, agrossman@ssih.org
May 8, 2018

Hi Maggie,

We've discussed your request and we see no problem with you posting this on SimConnect.

Please let us know if you have any further questions or concerns.

Best,

**Olivia Rosace | Customer Service Representative**
Society for Simulation in Healthcare

**Email to: iste@iste.org**
**From: [e-mail address redacted]**
**May 29, 2018**

Good morning,

My name is Maggie Marsh-Nation and I am an educational technology doctoral candidate at Walden University. I am a member of ISTE. I am doing a dissertation titled "Exploring the Use of Educational Technology in Neurodiagnostic Clinical Skills". I need to enlist the help of 15 experts in educational technology with at least a master's in education and experience in educational technology. If they have healthcare experience as well, all the better. They will participate in a Delphi study along with 15 experts in neurodiagnostic technology.

The study will take approximately one hour per week for three weeks. The identity of the participants will not be published or known to the other expert panel members. The names of participants will be known only to me and my dissertation committee. The only information about the expert panel that will be shared is the collective degrees, certifications and years of experience for the group in total. (example: 5 PhDs in Educational Technology, 4 Masters in Instructional Design, etc.)

I have seen other postings requesting participants to take part in studies. In filling out my IRB forms I need written permission (email) from the society. There will no reimbursement or gift. It will be completely volunteer.

Thank you for your help. I'd love a quick response as it is nearing the end of the quarter and I'd like to submit the IRB so I can finish up this quarter. I need a written (email) response giving me permission to post in one of the professional learning networks.

You can contact me at the numbers below. Try the voice number first as I live on the edge of town and my cell works well only when I leave home.

Thanks again,

Maggie

Maggie Marsh-Nation, MSIDT, R. EEG/EP T., CNIM

Doctoral Candidate in Educational Technology at Walden Univ.

[address redacted]
office phone: [redacted], cell: [redacted] fax: [redacted]

From: shelton@iste.org
May 30, 2018

Hi Maggie,

You’re welcome to post that in our forums! Perfectly compliant with our community guidelines.

Simon

--
**SIMON HELTON**
*Director of Community Engagement*
503.765.7415
iste.org