THE EFFECT OF POSTSECONDARY EDUCATION AND PREVIOUS WORK EXPERIENCE ON CLINICAL COMPETENCE: A QUANTITATIVE ANALYSIS OF NEURODIAGNOSTIC TECHNOLOGISTS' CREDENTIALING EXAMINATIONS

A Doctoral Thesis Presented to the
Faculty of the College of Education
University of Houston

In Partial Fulfillment
of the Requirements for the Degree

Doctor of Education

by

Sami F. Elestwani

May 2018

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Abstract

Background: Neurodiagnostic technologists are allied health professionals. They perform highly specialized diagnostic tests on patients of all ages. There is evidence of increased demand for well-educated neurodiagnostic technologists in the United States. However, the number of technologists who successfully pass the EEG credentialing examination is low when compared to other allied health professions. **Purpose:** This study is intended to answer the following research question: What are the effects of postsecondary education and previous work experience on neurodiagnostic technologists' vocational competence? **Methods:** This study used quantitative retrospective analysis of examination data from the Americana Board of Registration of Electroencephalographic and Evoked Potential Technologists written examination between 2010 and 2015. IBM SPSS Statistics was used to analyze these data and to test the study hypotheses. **Results:** The initial one-way MANOVA test, using examination version as the independent variable and examination pass rate and average scores as the dependent variables, indicated that there was a statistically significant difference between the results of the two examination versions. Secondary analysis also indicated that on average, examination pass rate and average scores are higher for examination version two when compared to those of examination version one. Further testing also indicated that the mean averages of pass rate and scores increased with higher levels of education. Surprisingly, this relationship was reversed for the number of years of relevant work experience.

Conclusion: The study revealed three major findings: 1) the change in examination format in 2013 resulted in a statistically significant increase in the examination pass rate and the average examination scores, 2) there is a significant positive correlation between level of education and neurodiagnostic technologists' competence, and 3) there is a negative correlation between the number of years of related work experience and technologists' competence.

Keywords: Neurodiagnostic Technology, Allied Health, Education, Examination Pass Rate, Work Experience

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Chapter I

Introduction

Neurodiagnostic (ND) "is the medical diagnostic field devoted to the recording and study of electrical activity in the brain and nervous system" (CAAHEP, 2009, p. 1). Neurodiagnostic technologists (ND techs) are the healthcare professionals who perform these diagnostic tests. They work hand in hand with physicians, surgeons, and other healthcare professionals in various settings such as hospitals, clinics, and private physician's offices. In these settings, ND techs perform diagnostic tests on patients with neurological, respiratory, and orthopedic disorders. Their scope of practice includes Electroencephalography (EEG), Long Term Epilepsy Monitoring (LTM), Evoked Potentials (EP), and Intraoperative Neurophysiological Monitoring (IONM). Although it is not mandatory, ND techs usually sit for one or more specialty credentialing examinations managed by the American Board of Registered Electroencephalographic and Evoked Potential Technologists (ABRET). The educational and work experience requirement for each credentialing examination varies by specialty. Although postsecondary education is not currently required to sit for any of the examinations, many ND techs, when the choice is available, choose to join a formal training program at a local community college or private institution.

The development of the ND technologists' profession has changed dramatically over the last 60 years, but not in a well-organized fashion until the late 1990's. Throughout much of the 20^{th} century, the development of skilled technologists has depended largely on apprenticeship (on-the-job training) programs. Therefore, the quality of that training depended exclusively on the trainers whose skills and knowledge varied widely (Knott, 1975). During the first half of the century, laboratory directors, mostly trained physicians, were responsible for the training of ND techs. However, this responsibility gradually transitioned to the senior ND technologist in the laboratory. The initial training for most of those senior technologists ranged from a few days to a few months of on-the-job training. Even basic ND technology teaching for neurology residents, in many cases, became part of the senior technologists' responsibilities. By the end of the 20th century, almost all ND technologists training became the responsibility of senior technologists. Most importantly, those senior technologists hailed from the ranks of hospital and office staff, many of whom have little or no college education and lack formal training (Head, 2004). This wide variability in the educational background of senior ND technologists resulted in varied educational qualities of on-the-job training programs.

Formal neurodiagnostic education did not exist until the late 1970's. Even now, there are only 23 formal training programs in the USA (CAAHEP, 2015). Most of the current formal educational programs' instructors are senior ND technologists with diverse education. The educational background of ND technologists has been the subject of many debates over the past few years (Erwin, 1976; Klem, 1976; Knott, 1984). This debate put forward some questions about ND education: Can on-the-job training produce competent and skilled ND technologists who are qualified to perform complex and sophisticated diagnostic procedures? Can the ND profession continue to progress without the knowledge afforded by formal specialized college-level education? This study will attempt to answer these questions while examining the licensing examination success rate of ND technologists who graduated from a formal ND educational program versus those who received on-the-job training, as well as examining the possible effect of postsecondary education on the overall competence of ND techs as measured by the credentialing examinations.

Historical Background

Established in 1964, The American Board of Registered EEG and EP Technologists (ABRET) is the leading credentialing body for neurodiagnostic Technologists (ABRET, 2015a). The Board of Registered Polysomnographic Technologists (BRPT) and the American Association of Electrodiagnostic Technologists (AAET) also issue credentials for ND Techs. However, they are only concerned with credentialing technologists in the areas of Sleep and Nerve Conduction Studies respectively. The current study will focus on ND technologists credentialed by ABRET only. The American Society of Electroeurodiagnostic Technologists (ASET) and the American Clinical Neurophysiology Society (ACNS) endorse ABRET issued credentials. Historically, ASET represents the technologists, while ACNS represents the physicians in the field of Clinical Neurophysiology.

Clinical Neurophysiology is a relatively new field of medicine. Although scientists have recorded electrical brain activities from animals since the late 1800s, the prominent German psychiatrist Hans Berger was the first scientist to record electrical signals from a human brain in 1924 (Neidermeyer & Lopes Da Silva, 2005). Building on his research, a group of three visionary scientists in 1935, described the characteristics of spike waves recorded from a human brain (Gibbs, Davis, & Lennox, 1935) and subsequently the field of Clinical Neurophysiology was born. Since then, the field of diagnostic neurophysiology grew exponentially, medically and technically. This growth dictated a parallel growth in the demand for trained professional technologists who perform diagnostic tests in this area.

The demand for trained ND techs grew substantially over the past few years. In its December 2013 Employment Projections, 2012-2022 report, the U.S. Department of Labor's Bureau of Labor Statistics projects a 0.5% annual labor force growth between 2012 and 2022. However, the same report projects a substantial 26.7% increase in health technologists' (including ND techs) employment (United States Department of Labor - Bureau of Labor Statistics, 2013). The report also predicts a 36% job growth rate for allied health instructors for the 2012 – 2022 period. The increasing trend in the number of registered EEG Technologists (R. EEG T.) since 2007 supports these predictions (Figure 1) (ABRET, 2015b). However, this increase in demand and supply of ND Techs is not paralleled by an increase in the number of specialized educational programs. According to the American Journal of EEG Technology, the United States had only ten accredited schools in EEG Technology as of January 1977 (Joint Review Committee on Education in EEG Technology, 1977). Now that number stands at a modest 23 accredited programs scattered across the nation (Commission on Accreditation of Allied Health Education Programs, 2015). Because of this disparity between demand and supply of educational programs, many hospitals, and individuals, created mentorship programs to train ND Techs. There is no data, however, to determine the success of these programs in supplying well-trained technologists. According to a 2015 ABRET report, out of the 448 candidates who took the second part of the EEG registry exam in 2014, only 277 technologists were successful (ABRET, 2015c). This result translates into a low 62% pass rate. The same report shows similar or worse results for other modalities (Evoked

Potentials and Intraoperative Neurophysiological Monitoring).

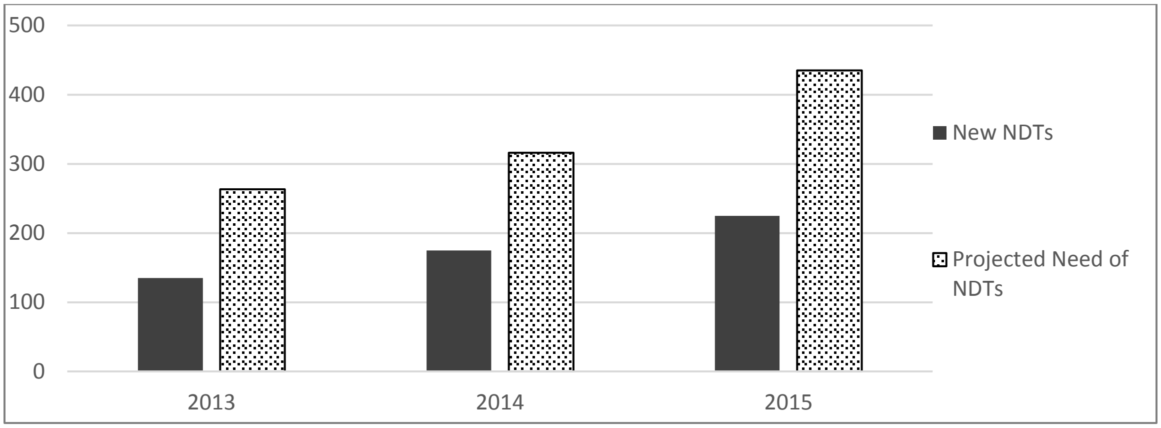

Figure 1. Number of New Registered EEG Techs (ABRET, 2015b)

Currently, ABRET offers credentialing in four subspecialties in ND: Registration in EEG (R. EEG T.), Registration in Evoked Potentials (R. EP T.), Certification in IONM (CNIM), and certification in long-term monitoring (CLTM). According to the new ABRET guidelines (ABRET, 2016a), effective January 2016, tables 1-4 show the defined Certification/registration paths for each subspecialty.

Table 1

Paths to R.EEG T.

	Eligibility Pathways	Educational Requirements	Work Experience Requirements	Continuing Education
Pathway I	CAAHEP Accredited NDT Program	**Graduate** of program or **Student** enrolled at least six months in program	None (Clinical Rotations)	None
Pathway II	Non-CAAHEP Formal NDT Education	Certificate of completion from ABRET recognized program	Documentation of 100 EEGs	None

Table continues

Table 1

	Eligibility Pathways	Educational Requirements	Work Experience Requirements	Continuing Education
Pathway III	Associates Degree or RPSGT	Associates Degree (or Higher) OR RPSGT	one-year clinical EEG experience and Documentation of 150 EEGs post experience	30 EEG ASET-CEUs
Pathway IV	Employed in Neurodiagnostics	High school Diploma	two years clinical EEG experience AND Documentation of 200 EEGs post experience	60 EEG ASET-CEUs

Table 2

Paths to R. EP T.

	Eligibility Pathways	Educational Requirements	Work Experience Requirements
Pathway I	CAAHEP Accredited NDT Program	Graduate - immediately eligible	None
Pathway II	Employed in Neurodiagnostics	Associate Degree	two years clinical Neurodiagnostic experience AND Documentation of 25 clinical EP studies. Ten recorded within the last year

Table 3

Paths to CNIM

	Eligibility Pathways	Educational Requirements	Work Experience Requirements	Continuing Education
Pathway I	CAAHEP Accredited NDT Program	Graduate of a CAAHEP NIOM Program or CAAHEP accredited add-on NIOM Program	Documentation of 50 NIOM cases	None

Table continues

Table 3

	Eligibility Pathways	Educational Requirements	Work Experience Requirements	Continuing Education
Pathway II	R. EEG T. or R. EP T.	HS Diploma	Employed in Intraoperative Monitoring with Documentation of 150 NIOM cases	None
Pathway III	Bachelor's Degree	Bachelor's Degree	Employed in Intraoperative Monitoring with Documentation of 150 NIOM cases	Documentation of 15 hours of relevant education Must be related to IOM & in the last five years.

Table 4

Path to CLTM

	Eligibility Pathways	Educational Requirements	Work Experience Requirements	Continuing Education
Pathway I	R. EEG T. Credential	None	One year as an R. EEG T. or RET (Canadian EEG Credential), one year of Long Term Monitoring Experience after the EEG credential is earned. Documentation of 50 LTM cases. Max of 3 cases per day.	Current CPR/BCLS certification

Statement of the Problem

The poor performance, 53% in 2014, on ABRET's EEG1 credentialing examination is alarming (ABRET, 2015c). Compared to other allied health licensing examinations in the United States, the ABRET examination success rate is extremely low. For example, The American Registry of Radiologic Technologists (ARRT) reports an impressive 94% examination success rate for nuclear medicine technologists (NMT) and an 89.6% for radiology technologists (RAD). This rate is remarkable given the number of examinees. In 2013, 555 and 13,392 candidates sat for the examinations for NMT and RAD respectively (The American Registry of Radiologic Technologists®, 2014).

Although many factors can affect the technologists' performance on the ABRET EEG credentialing examination, this study will focus on the possible effect of postsecondary education and work experience on the competency scores and the overall success rate in the EEG 1 credentialing examination. We will analyze the possible differences in the examination pass rates and competency scores for all EEG registration's available credentialing tracks. To achieve this goal, we grouped the examination results based on the educational background and work experience of candidates. Then we tested whether there are significant differences in the examination results between the groups.

Purpose of the Study

The purpose of this study was to examine the effect of postsecondary education (PSE) and previous work experience on the professional qualifications of ND technologists in the United States of America. While examining the possible factors influencing the current shortage in registered and certified ND technologists, an initial survey of available information published online by ABRET revealed that despite the limited number of ND educational programs available in the USA, as shown in figure 2, the number of candidates attempting the registration examination is higher than the projected number of ND technologists needed in the USA. However, the number of those who successfully pass the examination is significantly lower than the projected need.

Therefore, examining the possible effect of PSE on the ABRET examination's pass rate may provide the bases for a more in-depth look at the education of ND techs.

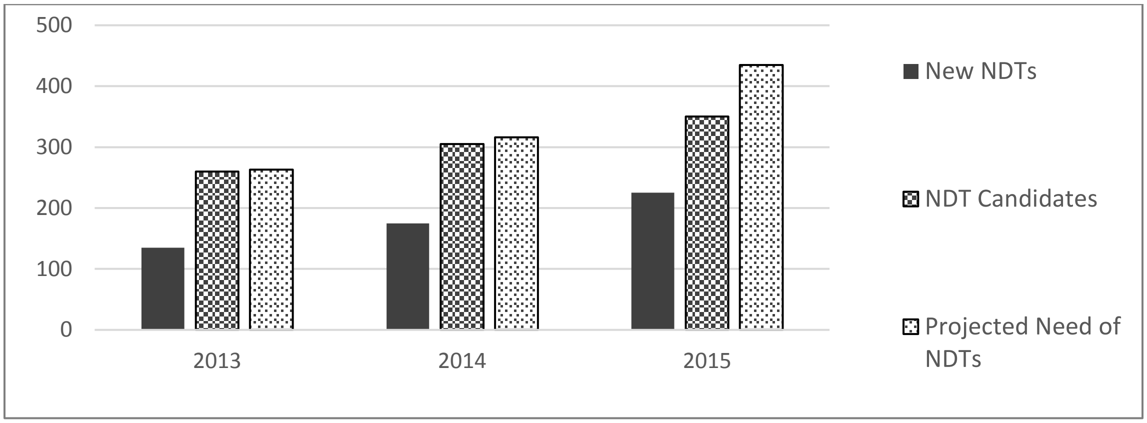

Figure 2. Demand and Supply of EEG Techs

ND techs scope of practice includes performing highly technical and complicated diagnostic procedures on patients with a wide variety of neurologic, pulmonary, cardiac, and orthopedic disorders. Physicians, mainly neurologists, rely heavily on the technical skills of ND techs. The medical community places greater importance on the ABRET registration and certification of ND technologists due to the absence of national and state-mandated licensing for those technologists. Therefore, ABRET issued registrations and certifications are the only proof of the technologists' competency afforded to the public and the medical community. ABRET also maintains that the examinations are true determinants of technologists' competence in each field of practice within ND. Given this, examining the pass rate of these examinations and relating it to the educational background of the examinees may provide good bases to understand the factors of success in NDT education. Additionally, this may help NDT educators to understand the relationship between postsecondary education and the examination pass rate. This process may also allow us to examine the overall effectiveness of ND techs education at various levels (On-the-job training versus vocational education).

Theoretical Framework

This study used the general system theory, as defined by Von Bertalanffy in the 1920's, to form the theoretical framework for studying the competency of the ND techs in the United States. Systems theory has its roots deep in the philosophical work of nineteenth-century philosopher Friedrich Hegel who argued that the whole is more than the sum of its parts and that the parts of the whole are dynamically interrelated (Gigch, 1974). Von Bertalanffy's General System Theory explains the inter-relationships of the micro-systems and their dynamic relationship to the macro-system. Furthermore, the General System Theory is a valuable "regulative device in science" (von Bertalanffy, 1950):

> The existence of laws of similar structure in different fields enables the use of systems, which are simpler or better known as models for more complicated and less manageable ones. Therefore, General System Theory should be, methodologically, an important means of controlling and instigating the transfer of principles from one field to another, and it will no longer be necessary to duplicate the discovery of the same principles in different fields isolated from each other. At the same time, by formulating exact criteria, General System Theory will guard against superficial analogies which are useless in science and harmful in their practical consequences. (p. 143)

The overall macro system of allied health education is a function of its microsystems: competency and behavior. While playing an important role in shaping the bigger picture, each microsystem is also a function of smaller systems. Additionally, the interdependency between systems is also an important feature of this theory. Within the macro system, each microsystem seeks to reach a state of equilibrium, and in-turn influences the equilibrium of other microsystems and the whole macro system as shown in Figure 3 below.

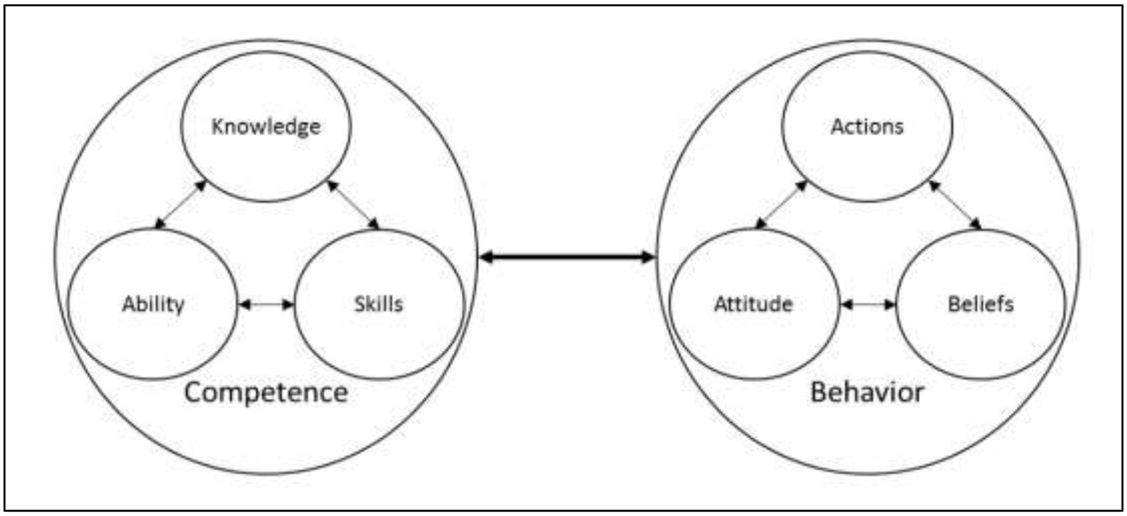

Figure 3. Allied Health Education

The General Systems Theory provides the bases for understanding the intricate relationships within the allied health education's environment. The individual factors: knowledge, skills, and abilities constitute the competency system. Work experience builds technical skills and abilities. Thus, we may conceptualize competence (C) in allied health as a function (f) of education (e) and experience (x); $C = f(e, x)$.

The level of vocational competence most probably involves a definable explicit interaction between experiential learning and didactic instructions. Within this context, the level of experiential learning level can be further defined as the summation of tasks performed under supervision times the length of time (τ) spent on each task (T): $\chi = \sum(\tau \times \mathrm{T})$. For every occupational role, a defined and measurable competency exists and is influenced by the level of on-the-Job / Vocational training received. The level of education achieved by each individual within that field and the level of experience moderate that level of competence (Figure 4). Within this relationship, we hypothesize a positive correlation between the level of education and competence. Therefore, as the level of postsecondary education increases, we would expect to see a positive change in the measurement of competence within the profession. Moreover, for each profession, a validated process, an examination, determines the level of competence. In addition, the Level of Experience contributes to the level of competence. Therefore, we also postulate that an increase in the level of experience may lead to an increase in the level of competence.

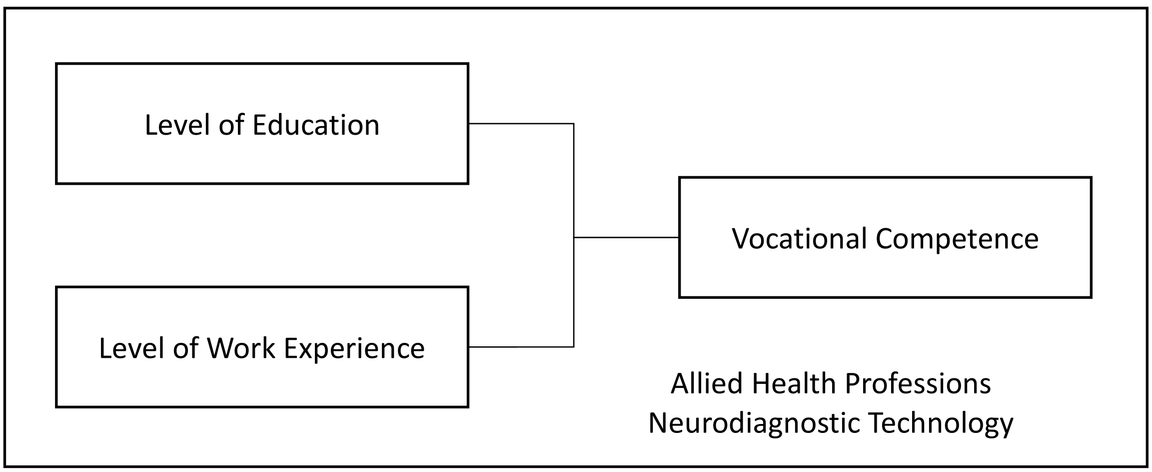

Figure 4. Theoretical Model

Research Question

The current study intends to provide the bases for understanding the effect of postsecondary education and previous work experience on the credentialing of ND technologists by attempting to answer the following question: What effect do Postsecondary Education and previous work experience have on neurodiagnostic technologists' vocational competence as measured by the registration examination? ABRET's registration examination measures vocational competence in five areas: 1) Patient history, 2) Common neurological disorders, 3) Patient preparation, 4) Basic EEG concepts, and 5) Instrumentation.

Context for the Study

This is a quantitative study based on archival credentialing examinations data available from ABRET examination reports. This study also utilized data available on allied health accrediting bodies' websites, and US Department of Labor databases. ABRET data consists of historical credentialing examination scores and pass rates of the three different modalities: EEG, EP, and IOM. Data will also include examination pass rates categorized by educational institutions where candidates received their ND education, candidates' educational background, candidates' years of experience before taking the examination, and the approximate number of procedures performed by candidates before the examination's application date. Other data will consist of published reports from various CAAHEP accredited ND training programs in the USA.

Significance of the Problem

This study addresses the education and competence of ND technologists. A scholar.google.com, on November 26, 2016, search using the term "ND technologist," "Neurodiagnostic technologist," or "Electroneurodiagnostic technologist" returned only 120 results. The results went down to 77 when we added "education" to the search terms. In comparison, the search returned 4,780 results for the same variation of "radiology technologist" and 2,430 results when we added "Education" to the search term. We obtained similar results for the allied health field of diagnostic medical sonography. We also obtained comparable results when we used other databases available through the University of Houston's library. These search results indicate a severe shortage in the literature addressing the education of ND technologists. Additionally, an overwhelming majority of the relevant literature on ND technologists' education was found in ASET's quarterly journal. This professional journal has been in publication since 1961, and it has undergone three name changes: American Journal of EEG Technology (1961-1995), American Journal of Neurodiagnostic Technology (1996-2011), and The Neurodiagnostic Journal (2012-Current). It is also important to note that none of the published articles in this area includes quantitative or qualitative research examining the education of ND technologists.

Educational Value of the Study

The current study will contribute to the sparse educational literature in the field of ND technology where there is a severe shortage of related literature. This study, although limited in scope, will play a positive role in the process of closing this gap in educational material. The current study will contribute to the limited body of knowledge in the area of ND technology education by attempting to draw attention to the importance of education in the field of ND technology. Furthermore, this study may lay the foundation for future studies aimed at establishing postsecondary education standards in ND and provide the basis for better understanding of the educational needs in the field of neurodiagnostic technology.

Definitions

This study uses terminology and acronyms that are specific to the technical field of neurodiagnostic. Additionally, the use of some terms such as on-the-job training, formal education, and vocational training in this text may differ slightly from the conventional definitions and thus require further explanation.

On-the-job training: within the context of this study, on-the-job training refers to

ND technical and clinical training provided by hospitals and clinics to newly hired employees (ND technicians) with no previous knowledge or training in the field of neurodiagnostic technology. Usually, an experienced trainer (typically a registered ND technologist) provides this type of training.

Postsecondary education: education received after high school at an educational institution, usually a community college or a four-year-degree-granting university.

Competency-based education: Educational programs designed to ensure that trainees achieve a certain level of competence in a specific field.

Vocational training: Training that focuses on developing the trainees' knowledge and skills needed to perform a specific job function. In the context of this study, the two terms vocational training and on-the-job training are used interchangeably.

Allied Health Profession: Allied health is a diverse group of healthcare professionals who use specialized training and knowledge for the diagnosis, evaluation, and treatment of a wide variety of diseases. They, amongst other things, work to promote the well-being of their communities and support the healthcare system in a wide range of settings. ND technology is a profession that is listed as "allied health" alongside many of the non-nurse and non-physician healthcare providers such as audiologists, physical therapists, radiology technologists, and dietitians. (The Association of Schools of Allied Health Professions, 2016)

For the following three terms, Registration, License, and Educational certificate we will use the definitions developed by the Institute of Education Sciences' (IEC) Interagency Working Group on Expanded Measures of Enrollment and Attainment.

Registration / Certification: A credential awarded by a certification body based on an individual demonstrating through an examination process that he or she has acquired the designated knowledge, skills, and abilities to perform a specific job. The examination can be either written, oral, or performance-based. Certification is a time-limited credential that is renewed through a recertification process.

License: A credential awarded by a government agency that constitutes legal authority to do a specific job. Licenses are based on some combination of degree or certificate attainment, certifications, assessments, or work experience; are time-limited, and must be renewed periodically.

Educational certificate: A credential awarded by an educational institution based on completion of all requirements for a program of study, including coursework and test or other performance evaluations. Certificates are typically awarded for life (like a degree). Certificates of attendance or participation in short-term training (e.g., one day) are not in the definitional scope for educational certificates. (Bielick, Cronen, Stone, Montaquila, & Roth, 2013)

Allied health is defined in the Federal Code and further defined in The Patient Protection and Affordable Care Act (ACA). The ACA (P.L. 111-148) defines allied health professionals as follows:

Allied Health Professional: The term "allied health professional" means a health professional as defined in section 799B(5) of the Public Health Service Act (42 U.S.C. 295p(5)). Those are professionals who: 1) have graduated and received an allied health professions degree or certificate from an institution of higher education; and 2) are employed with a Federal, State, local or tribal public health agency, or in a setting where patients might require health care services, including acute care facilities, ambulatory care facilities, personal residences, and other settings located in health professional shortage areas, medically underserved areas, or medically underserved populations, as recognized by the Secretary of Health and Human Services. (U.S. Government Publishing Office, 2010)

The following list represents explanations of the various terms and abbreviations used in this text:

Table 5

List of Acronyms

Term	Explanation
AAET	American Association of Electrodiagnostic Technologists - AAET is an organization for Nerve Conduction Study (NCS) Technologists. AAET administers and maintains a credentialing examination for the Registered Nerve Conductions Studies Technologist (R. NCS T). https://www.aaet.info/
AAN	American Academy of Neurology - The AAN is the world's largest association of physicians specialized in neurology https://www.aan.com/
ABRET	American Board of Registration of Electroencephalographic and Evoked Potentials Technologists - is the only body for credentialing of technologists and accreditation of laboratories in the field of Neurodiagnostic technology. http://www.abret.org/
ACNS	American Clinical Neurophysiology Society - is the major professional organization in the United States devoted to the establishment and maintenance of standards of professional excellence in clinical neurophysiology in the practice of neurology, neurosurgery, and psychiatry. http://www.acns.org/about-acns/history
ASET	American Society of Electroneurodiagnostic Technologists- is the professional society for ND Technologists in the USA. http://www.aset.org/
ASNM	American Society for Neurophysiological Monitoring. http://www.asnm.org/default.asp?

Table continues

Table 5

BRPT Table 5	Board of Registered Polysomnographic Technologists - is an independent, nonprofit certification board that cultivates the highest professional and ethical standards for polysomnographic technologists by providing the leading internationally recognized credential in sleep technology – the Registered Polysomnographic Technologist (RPSGT) credential. http://www.brpt.org/
CAAHEP	Commission on Accreditation of Allied Health Education Programs. http://www.caahep.org/
CoA-NDT	Committee on Accreditation for Education in Neurodiagnostic Technology. http://www.coa-ndt.org/
EEG	Electroencephalograph - a study of the electrical activities of the brain. http://www.mayoclinic.org/tests-procedures/eeg/basics/definition/prc-20014093
ND	Neurodiagnostic (ND) Technologists are trained professionals that specialize in studying and recording the electrical activity of the brain and nervous system. http://www.mshealthcareers.com/careers/electroneurodiagnostictechnologist.htm
EP	Evoked Potentials - studies that measure electrical activity in the brain in response to stimulation of the nervous system. http://www.hopkinsmedicine.org/healthlibrary/test_procedures/neurological/evoked_potentials_studies_92,p07658/
IOM	Intraoperative Neurophysiological Monitoring - Also IONM
NCS	Nerve Conduction Studies - studies that record the electrical activities of Muscles and peripheral nerves in response to electrical stimulation of peripheral nerves
R. EEG T.	Registered EEG Technologist
R. EP T.	Registered Evoked Potentials Technologist
R. NCS T.	Registered Nerve Conduction Studies Technologist
RPSGT	Registered polysomnography technologist

Limitations of the Study

The current study depended on the following: 1) archival data collected and reported by ABRET, and 2) on published data on program-outcomes by some CAAHEP accredited ND training programs. Consequently, the limited amount of data on examinations candidates limited the scope of the study. Although the quality of the educational program represents an essential aspect of the overall education of ND students, and it may influence their performance on the examination, it is important to acknowledge that many other factors may also play a role in this area. These factors may include the characteristics of the examinees, such as the number of examinees on which the rate is calculated, the qualifications of the trainers and instructors, and the adherence to published competency standards by instructors. Future studies may further examine the effect of trainers' qualifications and their teaching methods on the quality of education as measured by examination success rate.

Summary

Neurodiagnostic technologists are allied health professionals. They perform highly specialized diagnostic tests on patients of all ages. There is evidence of increased demand for well-educated and experienced ND techs in the United States. For example, according to a statement released by the University Of North Carolina School of Medicine, credentialed ND techs with some college education are more likely to assume leadership responsibilities at the workplace (UNC School of Medicine, 2015). However, ND techs are not required to have any college education to sit for the optional national credentialing examination. In a 2015 report, ABRET, the primary credentialing body for ND techs, expressed concern over the reported low pass rate on the board exam for the past few years (ABRET, 2015c). However, the report does not explain the declining examination pass rates. A relationship may exist between the exam success rate, the examinees' previous work experience, and the type of education the examinees received before taking the test.

The current study intends to examine the relationship between postsecondary education, previous work experience, and ND technologists' performance on the credentialing examination. A review of the literature on neurodiagnostic technology education will follow to provide support for the primary research question: What effect do Postsecondary Education and on-the-job/vocational training have on neurodiagnostic technologists' vocational competence as measured by the registration examination? The literature review will include a chronological overview of the literature on ND technology education, an outline of literature on vocational competence and its relationship to on-the-job training and work experience in allied health and will conclude with a summary of the possible relationship between postsecondary education and competence.

Chapter II

Review of the Literature

This chapter will outline the literature concerned with neurodiagnostic technologists' competence, on-the-job training, and education. Guided by the theoretical model presented earlier, this chapter will present: 1) a chronological overview of research and journal articles addressing ND techs on-the-job training and education, 2) an outline of literature on vocational competence and its relationship to on-the-job training and work experience in allied health, and 3) a summary of the possible relationship between postsecondary education and competence.

Introduction

The purpose of this study is to assess the influence of postsecondary education on ND technologists' competence, which may help provide the bases for a better understanding of the educational needs in the field of ND technology. Unlike medical education in clinical neurophysiology, technical education has not received much attention. This inattentiveness to the field resulted in an obvious lack of research in this field when compared to other allied health fields such as radiology, magnetic resonance, and medical-sonography technology.

An extensive search for available literature on ND education yielded an extremely low number of articles and a single abstract of an unpublished doctoral dissertation in 2008. PubMed search using "All databases" and the term "Neurodiagnostic technologists" returned three items. Only two articles out of the three are relevant to this study.

Although there are nationally accepted competencies for ND technologists, there is little to no research centered on the pedagogy of ND technology. Furthermore, there are no published quantitative studies that assess the quality and the effectiveness of current ND educational practices.

Out of the 23 accredited programs in the United States (Appendix A); only 14 active programs offer an Associate Degree in ND technology (CAAHEP, 2015). These numbers dwindle in comparison to the 737 accredited programs in radiography technology (The American Registry of Radiologic Technologists, 2005), 228 accredited physical therapy programs, and 333 physical therapy assistant programs (CAPTE, 2015). The scarcity of educational programs makes obvious the lack of attention afforded to the ND Technology education in the USA in specific and worldwide in general; it also correlates well with the lack of education research in this field.

Education and On-The-Job Training

On-The-Job training, also referred to here as vocational education and training (VET) can be broadly defined as the overall aggregation of purposeful activities designed to impart knowledge, skills, and competencies deemed essential to perform a function or a job. In the United States, as in Japan, Australia, and Canada, where the link between education systems and the labor market are limited, greater involvement of employers in vocational education and training is required. This involvement is achieved by the emergence of strategic partnerships between employers and vocational training systems, or by creating systems of placement during training (Descy & Tessaring, 2001). The ND technology field in the U.S. followed, to a certain extent, this model. From its birth, ND technology relied heavily on employers to advance its education and training. Similarly, educational programs depended on placement systems to strengthen its link to the labor market.

Clinical EEG started in the USA in late 1936 and early 1937. John Knott, Ph. D., Professor of Neurology, Boston University School of Medicine; Professor of Psychiatry Tufts University School of Medicine; and Professor-Emeritus, Neurology and Psychiatry, University of Iowa, is regarded as the father of EEG technologists' education in the United States. In a 1984 article in the American Journal of EEG Technology, Dr. Knott documented the history of educational efforts in EEG Technology (Knott, 1984). While working in Dr. Fredrick Gibbs' EEG research laboratory, Dr. Knott described the first "EEG Technician" he ever saw as a research secretary at Boston City Hospital, who helped prepare Dr. Gibbs' patients for the test, and sometimes she recorded the EEG studies as well. Soon after, others entered this new technical field. They often rose through the ranks of secretaries or other laboratory assistants. The new EEG technicians usually received two to three days of on-the-job training (OJT). The instructions were simple: while the trainee watched, the trained physician demonstrated the method of applying the EEG Electrodes and starting the recording session (Knott, 1984). This basic idea of on-the-job training has not changed much since 1936, except that the training now takes much more time and includes slightly wider primary education, in some cases.

In 1946, The American Electroencephalograph Society (AEEGS) was found (ACNS, 2015). AEEGS later was renamed The American Clinical Neurophysiology Society (ACNS) in 1996. It is the leading organization concerned with clinical neurophysiology education for physicians. During its first annual meeting, in 1947, the AEEGS introduced new standards for EEG Instrumentation, EEG procedures, education and training, and certification of EEG clinicians (Yudofsky & Hales, 2008). Subsequently, the field of clinical neurophysiology experienced a growth spurt throughout the 1940's and 1950's (Stone & Hughes, 2013). In May 1958, a report drafted by a committee of highly regarded neurologists recommended that ND technologists do not need to have a University degree, rather a couple of months of on-the-job training would suffice. The report also included the committee's recommended training syllabus for technologists. These recommendations specified "elementary" and "basic" level education in the areas of electronics and human anatomy (The Committee on The Status, Recruitment, and Training of Students in Electroencephalography and Clinical Neurophysiology, 1958). These recommendations became the standards for technologists training at that time (Knott, 1975). Most EEG laboratories during that period established their on-the-job programs. However, these programs remained local, and their experiences never extended beyond the walls of their originating institutions. The on-the-job training remained the only entry method to ND technology until the late 1970's (Head, 2004). According to Klem (1976), Dr. Knott asserted in a 1976 ASET sponsored roundtable discussion on ND education that:

> for there to be true advances in clinical EEG, it would seem necessary that new recognition be granted by the neurological group to the truly professional EEG technologist. Such a recognition should be at the level of a neurologist's assistant in clinical EEG. An entirely new set of educational perspectives should be drafted. **A 4-year Bachelor of Science degree program should be the end result**. Accomplishing this will require the collaborative efforts of the most farsighted members of both the American EEG Society and the American

> Society of EEG Technologists. It will mean the phasing out of the ill-prepared "readers" now proliferating at a frightening rate, and of the even more ill-prepared (translate to "unprepared") techpersons serving them who seem to proliferate at an even more frightening rate. (p. 80)

Almost 40 years later, Dr. Knott’s call for a four-year Bachelor of Science program in neurodiagnostic, still has not materialized yet. The current lack of a four-year program is in no way a reflection of Dr. Knott’s vision. Instead, it reflects the inattentiveness of the neurodiagnostic community to the profession’s needs, as it is evident in the scarcity of literature and research on the subject of ND techs education.

In 1977, ASET published a report listing ten accredited vocational schools in EEG technology (American Journal of EEG Technology, 1977) (Table 6). The list included some of the most prestigious medical and educational institutions, such as Barrow Neurological Institute, Duke University, Louisiana State University, and the University of Alabama. It is unknown how many students benefited from these programs. In 1979, the list of accredited ND training programs grew to 14 (American Journal of EEG Technology, 1979) (Table 7). Most of these programs were hospital-based and considered, to a certain extent, as on-the-job or vocational training programs. Except for Orange Coast College, these programs did not offer any postsecondary degree or certificate to their students. They merely trained their students to be EEG technologists. Furthermore, out of the original ten programs, only one program continued in existence in 2015. This may be an indication of the lack of continuity in ND technology education. It is also worth mentioning that, despite the lack of formal educational programs, the five years following the 1977 report witnessed an increase of 63% in the number of newly registered EEG technologists (Table 8) when compared to the average number of EEG technologists for the five years prior to the publishing of the report (ABRET, 2015b). This increase in newly registered technologists may indicate a positive role of accredited EEG programs in preparing new EEG technologists for ABRET's EEG registration examination.

Table 6

Accredited ND Training Programs in 1977 (AJEEGT, 1977)

1977 Accredited ND Training Programs	Program Duration
Barrow Neurological Institute of St. Joseph's Hospital and Medical Center	two-year program
Duke University Medical Center	one-year program
Louisiana State University Medical Center	one-year program
Orange Coast College	two-year program
Presbyterian Hospital, Columbia-Presbyterian Medical Center	one-year program
United Hospital	Unknown
The University of Alabama in Birmingham	one-year program
University of Texas Medical Branch - Galveston College	one-plus-year year program
Veterans Administration Hospital	Unknown
Western Wisconsin Technical Institute	one-year and two-year program

Table 7

Accredited ND Training Programs in 1979 (AJEEGT, 1979)

1979 Accredited ND Training Programs	Program Duration
Barrow Neurological Institute of St. Joseph's Hospital and Medical Center	two-year program
Crozer-Chester Medical Center	one-year program
Duke University Medical Center	one-year program
Herman Hospital/M. D. Anderson Hospital	one-year program
Laboure Junior College/Boston University	two-year program
Louisiana State University Medical Center	one-year program

Table continues

Table 7

1979 Accredited ND Training Programs	Program Duration
Orange Coast College	two-year program
Presbyterian Hospital, Columbia-Presbyterian Medical Center	one-year program
St. Joseph's Hospital	one-year program
United Hospital	six-month program
The University of Alabama in Birmingham	one-year program
University of Texas Medical Branch - Galveston College	One+ year program
Veterans Administration Hospital	one-year program
Western Wisconsin Technical Institute	one-year and two-year program

Table 8

Five-year average of new R. EEG T. before and after 1977 (ABRET, 2015b)

Period	Number of newly registered technologists
Average number of new registered EEG Technologists between 1972 and 1976	72
Average number of new registered EEG Technologists between 1978 and 1982	118
Change in five-year Average	46
% Change in Average	63

Although there was a considerable increase in the number of EEG training programs following Dr. Knott's 1976 recommendations, most training programs remained hospital-based while few were housed in community colleges. Meanwhile, throughout the remainder of the 20th century, ND education continued to be, overwhelmingly, the result of individual efforts. Unfortunately, just as Dr. Knott predicted in 1976, this growth in ND technology brought with it an alarming number of underprepared technologists. With that in mind, professional organizations such as ASET, ABRET, and CoA-NDT worked tirelessly on preserving the integrity of the ND field through the introduction of professional standards, credentialing, and nationally accepted competencies. In contrast to the call for the elevation of ND technology education to higher levels, Ivar Berg (1973) and Robert Quinn (1975) among others advocated reducing the overall education levels of the American workforce. Dr. Berg asserted that better-educated employees are less productive, and that employee's turnover rate is positively associated with high education. Meanwhile, Quinn asserted that "overeducated" workers suffer from dissatisfaction with one's employment, and with oneself.

All the above leads us to believe that the educational needs in the field of ND technology are not well defined. Although there were multiple calls for establishing postsecondary educational programs at university level, the inability of ND technology clinical and technical community to unite in defining higher education standards left ND techs education in a state of uncertainty.

The Role of Professional Organizations

ACNS.

The American EEG Society (AEEGS), renamed American Clinical Neurophysiology Society (ACNS) in 1995, is the first professional society in the United States dedicated to the advancement of clinical neurophysiology. From its inception in 1946, AEEGS dedicated considerable resources to the establishment of standards of "professional excellence" in the field of clinical neurophysiology (ACNS, 2015). ACNS develops and publishes technical and clinical standards and guidelines for clinical neurophysiology procedures (ACNS, 2013).

In 1959, under the leadership of Dr. Peter Kellaway, AEEGS helped a group of dedicated EEG technologists establishes a focused independent professional group concerned with the advancement of EEG technologists, namely the American Society of EEG Technicians. ASET became the primary group concerned with the education of ND technologists.

In 2006, ACNS published ND revised practice guidelines, in which it specified the minimum qualifications required to perform an EEG. Although it deferred specifying the exact qualification of ND technologists to other allied organizations, ACNS' Guideline 4, encouraged ABRET's credentials as an entry-level requirement for technologists, and specified a minimum of 6-month of supervised clinical experience, post-formal training before ND technologists operate independently (ACNS, 2006).

ASET.

The first attempt to organize the technologists under the umbrella of a professional association came in 1959. The late Dr. Peter Kellaway, Professor of Neurology at the Baylor College of Medicine, was influential in the creation of the American Society of Electroencephalographic Technicians (ASET) when he chaired the Technician's Committee of AEEGS (Mizrahi, Pedley, & Appel, 2004). Dr. Kellaway's recommendations for a technologists' certification process were adopted fully in ASET's first organizational meeting in June 1959. Dr. Kellaway also submitted to the technicians present at the meeting the proposed constitution which, among other things, defined the purpose of this society. The first four points of Article II of the approved constitution highlighted the educational vision of the new society of ND professional (ASET, 1959). However, ASET's new charter did not address the details of educational requirements for ND professionals, nor did it attempt to prescribe a minimum educational background for entry-level technicians.

ASET's launch in 1959 ushered the recognition of the new group of professionals, ND technologists, and the subsequent recognition of the field of ND technology by other technical specialties (Wallbert & Ahn-Ewing, 2009). It also set forth the necessity of establishing a credentialing board for ND professionals. Following a series of technical meetings, brainstorming sessions by groups of physicians and technicians, and exhausting efforts by activist technologists, ASET established a board of registration as a standing committee (Smith, 1984, & Zenishek, 1999). This standing committee later became the nucleus of the American Board of Registration of Electroencephalographic and Evoked Potentials Technologists (ABRET).

ABRET.

ABRET is the main credentialing body in the neurodiagnostic technology field. It is responsible for credentialing ND technologists as well as certifying neurodiagnostic laboratories. ABRET stated goals of the credentialing examination include: "1) to validate safe and effective job performance; 2) to evaluate job-related skills and knowledge; and 3) to provide an independent assessment and documentation of competency" (ABRET, 2016b). ABRET, by default, became the sole competency curator for the field of neurodiagnostic. ABRET maintains that all its credentialing examinations go through an extremely rigorous validation process and that their results are accurate measures of the technologists' clinical and technical competence. However, many physician-educators have expressed frustration over the historically low pass rate of the ABRET EEG examination (Erwin, 1976). In the same article, Dr. Erwin goes on to diagnose the low pass rate as a direct consequence of inadequate training. He also asserted that graduates of formal accredited training programs would undoubtedly achieve a much higher pass rate on this sole measure of clinical and technical competency.

ABRET requires that candidates achieve a minimum level of clinical and technical competency before attempting the credentialing examination (ABRET, 2016b). However, the process of acquiring the desired level of competence is not well defined. On-the-job training has been the most dominant method for obtaining the knowledge and skills necessary to achieve this level of competence. However, the examination pass rates over the past 50 years do not support the idea that this method is effective in producing competent technologists.

Overview of National Alternative Education Data

Evidence from social science research shows that there is a strong correlation between education and personal accomplishment (Hout, 2012). Most researchers base this evidence on conventional methods of measuring educational achievement: high school diplomas, associate degrees, bachelor's degrees, and advanced degrees (Ewert, 2014). However, the interest in a more skilled workforce had researchers and policymakers turn toward educational credentials, which have marketplace value, outside the traditional colleges and universities. In his 2009 State of the Union address, President Obama acknowledged the importance of such credentials when he asked "every American to commit to at least one year or more of higher education or career training... [including] community college or a 4-year school; vocational training or an apprenticeship." (Obama, 2009). Researchers also started to examine the role of alternative credentials in job placement and career advancement (Kleiner & Krueger, 2010). However, there is a shortage of available data on alternative educational credentials. This shortage may be explained, to a certain extent, by the availability of several pathways that people take to attain such credentials. Most national surveys have not started to collect this type of data until recently (Bielick, Cronen, Stone, Montaquila, & Roth, 2013). Between 2009 and 2012, The IEC put forth a focused effort to fill this gap in the census data. This effort resulted in the inclusion of questions on Professional Certifications, Licenses, and Educational Certificates in the Department of labor's Survey of Income and Program Participation (SIPP).

In 2012, SIPP data revealed that over 11 million U.S. high school education or less, who never attended a postsecondary institution, held a certification or a license in a professional field. The data also showed that although 28% of all U.S. employed adults held licenses or certifications, 13% of those classified as unemployed and 10% of the "not in the labor force" adults held them too (U.S. Census Bureau, 2012).

While traditional educational pathways provide a proven way for people to acquire new knowledge and skill sets, data shows that it is not the only avenue. Millions of U.S. workers have chosen alternative education pathways to gain new skill sets and improve their career prospects. Additionally, over a quarter of U.S. adults hold a certification, license, or educational certificate in addition to their traditional education degree (U.S. Census Bureau, 2012). The SIPP report also shows that adults with an associate degree or less who hold a professional certificate or license earn significantly more than those who do not hold them; and that most adults in that category are concentrated in the production and craft occupations. By definition, holding a professional certificate or license implies an added level of education not accounted for in the traditional classifications of educational attainment.

In the field of ND technology, there are no published data on the prevalence of traditional education degrees, beyond high school, among technologists. Additionally, some facts may lead to the belief that ND techs do not follow the national trend described above. These facts are: 1) lack of 4-year degree programs in ND technology, 2) a limited number of programs offering an associate degree, and 3) ASET and ABRET's requirement of only a high school diploma (or equivalent) for an entry-level position in ND technology. Given that a professional certificate in ND technology is proof of competency, this study aims to address alternative education in ND technology and the possible effect of traditional education on the professional certification process.

Competence

There is a recognized variation in the literature when it comes to the definitions of competence and competency, both in terminology and concept (Westera, 2001). Although at times used interchangeably, a competency is a skill, knowledge, or ability; while competence is the state of being able to apply that knowledge or skill (Birnbaum & Daily, 2009). The broad spectrum of competence definitions ranges from competence as a global quality, such as literacy, to competence as a specific individual ability to perform a task (Delamare Le Deist & Winterton, 2005). Arnold and Schussler (2001) define competence as the ability of a person to act autonomously; it is more holistic, encompassing subject and content knowledge as well as general and core capabilities. Mandon and Suzler (1998) assert that the concept of competence serves as a heuristic function; they contend that competence must be understood as knowledge, abilities, and qualities in action. Clinical competence is "… the habitual and judicious use of communication, knowledge, technical skills, clinical reasoning, emotions, values, and reflection in daily practice for the benefit of the individual and community being served" (Epstien & Hundert, 2002, p. 226). For this study, we will define competency as the skill itself, and competence as the capacity to perform that skill. For example, in the practice of ND technology, applying electrodes on a patient's head is a competency, while competence is the ability of an ND technologist to apply electrodes on a patient's head accurately and efficiently. The action of accurately applying electrodes requires knowledge, psychomotor skills, and attitude of how to apply the electrodes.

In ND technology, professional societies: ASET, ABRET, and ACNS define a set of competencies for each subspecialty in the field. These sets of competencies are based on practice analysis of the specific areas of ND technology: EEG, EP, CNIM, CLTM, and CAP. For example, EEG practice analysis defines four domains of practice: 1) Pre-Study Procedures; 2) Performing EEG Study; 3) Post-Study Procedure; 4) Ethics and Professional Issues (ABRET, 2016c). Each domain includes a list of tasks and a list of specific knowledge applied by competent ND techs (Appendix B). The knowledge, skill and ability statements listed in the practice analysis are used to generate competencies for registration and certification examinations. However, there are no data available on the validation process used to confirm these competencies. Additionally, there is no explicit mapping of the various EEG1 examination sections to the four domains identified by the EEG practice analysis. According to ABRET's EEG1 examinations reports, the areas of competencies tested are 1) Patient History; 2) Common Neurological Disorders; 3) Patient Preparation; 4) Basic Neurophysiology Concepts in EEG; and 5) Instrumentation.

Vocational competence.

Vocational competence is broadly defined as broad knowledge, skills, and attitude relevant to a specific industry. A person who is vocationally competent would possess relevant knowledge, skill set, and attitude, usually combined with relevant qualifications and work experience, in a particular area. Within this context, the term knowledge is inclusive of declarative, procedural, and metacognitive knowledge. Declarative knowledge is the collection of facts a person knows (Anderson & Schunn, 2000). Connecting the various pieces of declarative knowledge is procedural knowledge. Knowing about the context, critical-thinking, and self-awareness is metacognitive knowledge (Krathwohl, 2002). The three types of knowledge can be associated with three dimensions of vocational competence: conceptual competence, procedural competence, and interpretive competence (Greeno, Riley, & Gelman, 1984).

Conceptual competence requires knowledge of facts and possession of factual information about a subject. For example, in ND technology, a technologist seeks out and acquire facts about diseases of the nervous system and their effect on EEG. This competency is usually accomplished by a self-learning process, such as reading research articles or listening to lectures on the specific subject. The technologist may also seek to acquire facts and information on how to perform an EEG, without actually doing the test itself. By that, the technologist would be working towards achieving Conceptual Competence.

Procedural competence incorporates not only the how to do but also the action of doing, i.e., application of knowledge. For example, an ND tech achieves procedural competence in recording an EEG after learning the procedure and developing the motor skills of how to place electrodes on a patient's head, and how to operate the available EEG instrument. Procedural competence is usually accomplished through theoretical, technical, and hands-on supervised training.

The higher-level dimension of competence, interpretive competence, requires the ability to connect, integrate, and synthesize knowledge in a consistent decision-making process. Critical thinking skills are essential to achieving this level of competence. Critical thinking is a vital outcome of universities' core curriculum (Facione, Sánchez, Facione, & Gainen, 1995). Terenzini, Springer, Pascarella, and Nora (1995) concluded that university-level classroom/instructional experiences make significant positive contributions to gains in students' critical thinking. Therefore, postsecondary education may be considered essential to achieving interpretive competence.

Table 9

Competence and Knowledge

Competence Dimensions	Knowledge	Facilitator
Conceptual	Declarative	Readings / Lectures
Procedural	Procedural	Technical training
Interpretive	Metacognitive	Critical thinking

Assessing competence.

Competence is a function of education and experience; experience is a time function of training; therefore, acquisition of competence is driven by education, experience, and training. This relationship also indicates that competence is a dynamic process and develops at various stages. Which also means that assessing competence is a complicated process, and most frequently takes place in stages.

Significant progress has been made in the field of assessment of professional competence in health care. Many valuable lessons had been learned in professional evaluations (van der Vleuten, Schuwirth, Scheele, Driessen, & Hodges, 2010). In general, academic programs have employed traditional methods for assessing clinical competence. In health and professional programs, written examinations are most prevalent. Multiple-choice questions are believed to be objective, easy to administer and produce the most reliable results (Panzarella & Manyon, 2007). These we universally accepted for licensing in the medical field since the 1940's (Veloski, Rabinowitz, Robeson, & Young, 1999). Although multiple-choice examinations are popular and have been used universally across multiple academic disciplines, they are often poorly written and, in many cases, may produce false-positive results by overestimating students' problem-solving abilities (Feeley, Manyon, Servoss, & Panzerella, 2003).

Clinical and technical competence of ND techs is a direct outcome of training programs. ABRET currently uses multiple-choice questions examinations to assess this outcome. In addition to the series of formative and summative assessments implemented in the majority of allied health education and training programs, ND technologists must take a summative assessment, the ABRET certification examination.

ABRET contends that its examinations development process is rigorous, and is designed to achieve the following: (a) validate safe and effective job performance, (b) evaluate job-related skills and knowledge, and (c) provide an independent assessment and documentation of competency (ABRET, 2016b). The ABRET Examination Development Committee (EDC) works closely with select credentialed technologists who are considered subject matter experts (SMEs) and psychometricians to produce a Job

Analysis document for each subspecialty, which becomes the blueprint for the examination (Appendix C).

Summary

Literature and research on ND technology education are extremely scarce and mostly published in the professional journal of the neurodiagnostic Society of ND technologists. Most of the literature on this subject consists of opinion articles and conferences and meetings proceedings. There are no published quantitative or qualitative research reports addressing the educational needs and requirements of ND techs. However, general research on education, training, and competence can help inform the discussion on the relationship between ND technology competence, training, and postsecondary education.

The conceptual framework of this study is based on von Bertalanffy's discussion of general system theory. The open microsystem of competence maintains a multilevel balance internally and with other microsystems within the macrosystem of ND technology. The dynamic relationship between knowledge, skills, and abilities balance the competence microsystem. This study intends to look at this dynamic relationship by examining the possible effect of postsecondary education and work experience on ND techs competence. A detailed description and discussion of the methods that will be used to acquire and analyze data will follow.

Chapter III

Methodology

This research was driven by the desire to understand the phenomenon of the low pass rate of neurodiagnostic (ND) technologists on the national credentialing examination in the United States. Understanding this phenomenon requires an analysis of the American Board of Registration of Electroneurodiagnostic Technologists (ABRET) examination results over an extended period. For this purpose, we used archival examination data available from ABRET between the years 2010 and 2015.

Examining the state of ND technology education in the United States is a major undertaking. There are no evidence-based studies in this field that examines the role of post-secondary education in the clinical competence of ND technologists. An examination of available research showed a limited number of studies focusing on other allied health professions, most of which use descriptive statistics to describe the various educational programs' outcomes.

ABRET collects a wealth of information on examination candidates through the application process and other surveys. However, there are no published investigations, or analysis that examine whether there is any suggested correlation between the candidates' educational background and the examinations outcomes. The archival data which were obtained from ABRET consist of anonymous examinations raw scores and aggregate examination data organized by the candidates' educational background and years of experience in the field. These data are organized according to the paths to licensing described in Chapter one and reported in five areas of competency; these are 1) Patient history, 2) Common neurological disorders, 3) Patient preparation, 4) Basic EEG concepts, and 5) Instrumentation.

The purpose of this study was to examine the possible effect of postsecondary education (PSE) and previous work experience on the professional qualifications of ND technologists in the United States of America. While examining the possible factors influencing the current shortage in registered and certified ND technologists, an initial survey of available information published online by ABRET reveals that despite the limited number of ND educational programs available in the USA, the number of candidates attempting the registration examination is higher than the projected number of ND technologists needed in the USA. However, the number of those who successfully pass the examination is significantly lower than the projected need. Therefore, examining the role of PSE in the ABRET examination's pass rate may provide the bases of a better understanding of the education of ND techs, and may be helpful in laying the groundwork for NDT education guidelines in the future.

Research Question

The current study intended to provide the bases for understanding the role of postsecondary education and work experience on the credentialing of ND technologists by attempting to answer the following question: What effect do Postsecondary Education and previous work experience have on neurodiagnostic technologists' vocational competence as measured by the registration examination?

Data Sources

This study was based on archival data produced by ABRET between the years of 2010 and 2015. These data consisted of anonymous examination scores for the total number of candidates who attempted the EEG1 ABRET licensing examinations between 2010 and 2015. These totals were organized according to the licensing examination paths available. These examinations are administered three times per year for each examination path. ABRET provided neither demographic data nor individual examinations scores and individual educational background of candidates. However, educational background is a category by which specific paths to licensing are defined. Hence, we were able to examine the possible differences in exam pass rate and competencies scores based on educational background and level of experience. General descriptive statistics, including some demographic distributions, were provided for each examination instance. The total number of participants was approximately 3000 candidates.

Data Collection Procedure

The examination reports were available through ABRET's public website. The data was in adobe acrobat (.pdf) format and required some reformatting before importing it into IBM SPSS® for statistical analysis.

Data Analysis

We used IBM SPSS® version 25.0 for data analysis due to a large number of data points available for analysis. Initially, we produced descriptive statistics report. SPSS' ANOVA (Analysis of Variances) is commonly used to test the significance of the differences within and among groups. One-way ANOVA is used if the independent variable has two levels, while one-way MANOVA is used if the independent variable has multiple levels (Glen, 2017). The MANOVA test is preferred over t-test when examining comparisons of multiple samples means. MANOVA allows testing the equality of multiple samples means while holding the type I error rate at the predetermined α level for all the comparisons (Horn, 2009). To determine the effect size, we used Tukey HSD for Post-Hoc Analysis.

The results of the data analysis are reported in the next chapter. Discussion and explanation of the analysis are presented in the conclusion of this thesis.

Study Variables.

This research used archival data available from reports published by ABRET and PTC between the years 2010 and 2015. The variables in these reports include test scores, average examination pass rates, and the average overall scores, in addition to aggregate scores for each of the five clinical competencies, described earlier. The examinations reports are also grouped by the highest level of education achieved by candidates, and the total number of years of experience reported by the candidates at the time of the application. Table 10 lists the variables used in this analysis.

Table 10

Study Variables

Independent Variables	Dependent Variables
Highest Level of Education	Average Examination Pass Rate
Number of Years of Experience	Average Examination Score

The Instrument.

This study examined the relationship between the highest level of education achieved by candidates and their work experience levels with the average overall examination scores and the examination pass rate. The highest level of education achieved by each candidate and the number of years of clinical experience in this field (the independent variables) are hypothesized to play a role in the level of the overall clinical competence of neurodiagnostic technologists. The overall average scores of the examinations and the examination pass rate are the dependent variables.

ABRET's examination committee is responsible for developing and compiling questions for the EEG1 examination based on an in-depth practice analysis. Appendices B and C list the details of the neurodiagnostic technology practice analysis and the exam development process. The examination's item validity measures are included in each examination report.

Research hypotheses

This study used a quantitative retrospective analysis of examination data of ABRET's EEG written examination. This research used examination report data produced, after each examination, by ABRET and the examination administrators Professional Testing Corporation (PTC). These reports consist of four major sections:

1. Summary - Number passing and failing with average percent correct for each group, and the total group
2. Frequency Distribution of Total Test Scores - Total Group
3. Testing Center Summary
4. Summary of Examination Results by Testing Date (Raw examination scores).

We extracted data from these reports, coded the data, and used IBM's SPSS® Statistics version 25 to 1) produce a descriptive statistics tables to describe the examinations results, 2) compare and contrast different groups' scores and pass rate, and 3) perform a correlation analysis of the examinations' reported data to determine the role of education level and previous work experience in the overall examination pass rate and the overall competency scores.

The first step in the analysis was to test for the normality of the data to determine whether these data can be analyzed using multiple regression. For this purpose, we used the Kruskal-Wallis Test of normality for independent samples. Vargha and Delaney (1998) stated that the Kruskal-Wallis H test is the preferred method when comparing more than two independent samples. When used in SPSS, the statistical software produces a summary table stating the null hypothesis and the significance. In SPSS the null hypothesis is stated in positive terms, and a significance above 0.05 suggests retaining the null hypothesis.

The second step in this process included coding the data according to the highest academic level attained by the candidates and the number of years of relevant work experience. This process facilitated testing the difference in the examination pass rate between the various groups based on the educational background and work experience. This step also enabled us later, during data analysis, to perform a correlation analysis to determine nature of the relationship between the four variables used in this study. As such, we postulate:

Null Hypothesis One. There is no difference in the performance on ABRET examinations between candidates with various educational backgrounds.

Alternative Hypothesis One. There is a difference in the performance on ABRET examinations between candidates with various educational backgrounds.

Null Hypothesis Two. There is no difference in the performance on ABRET examinations between candidates with various levels of related work experience.

Alternative Hypothesis Two. There is a difference in the performance on ABRET examinations between candidates with various levels of related work experience.

Multivariate Analysis of Variances

Following the hypotheses tests, we will perform a multivariate analysis of the examinations' reported data to determine the role of PSE and previous work experience in the overall examination pass rate and the various competency areas scores. SPSS' MANOVA (Multivariate Analysis of Variances) is commonly used to test the significance of the differences within and among groups when dealing with more than one independent variable. One-way ANOVA is used if the independent variable has two levels, while one-way MANOVA is used if the independent variables have multiple levels (Glen, 2017). The ANOVA test is preferred over t-test when examining comparisons of multiple samples means. MANOVA allows testing the equality of multiple sample means while holding the type I error rate at the predetermined α level for all the comparisons (Horn, 2009).

Summary

The purpose of this study was to examine the possible effect of postsecondary education (PSE) and previous work experience on the professional qualifications of ND technologists in the United States of America. This study used quantitative retrospective analysis of examination data from the Americana Board of Registration of Electroencephalographic and Evoked Potential Technologists written examination between 2010 and 2015. IBM SPSS Statistics was used to analyze these data and to test the study hypotheses.

Chapter IV

Results

Introduction

The present study was dedicated to evaluating the effect of postsecondary education and previous work experience on the clinical competence of neurodiagnostic technologists as measured by the EEG1 examination offered by the American Board of Registered Electroneurodiagnostic Technologists (ABRET). EEG registration is important for neurodiagnostic technologists as a proof of competence in this allied health field. Therefore, an examination that can certify that they have these clinical competencies is a vital tool for these medical professionals.

In this chapter, the findings regarding the sample, descriptive statistics on the examination scores, analysis of variances in the examination pass rate, and a discussion of the various components of the examination will be presented. For this purpose, the examination reports between 2010 and 2015 were analyzed using IBM SPSS statistics software. Two sections of the reports were included in the analysis: 1) Highest educational level achieved, and 2) Number of years of related work experience at the time of the examination. The examination reports contain aggregate pass rates and competencies scores for all candidates who sat for each instance of the examination. A total of 16 reports were analyzed.

In 2013, ABRET changed the examination reporting structure of competencies. 2010 through 2012 reports included, in addition to the overall examination pass rate and the overall competency scores, the scores on four competencies: 1) Pre-Study procedures,

2) Performing the EEG study, 3) Post-Study procedure, and 4) Ethics and professional issues. The 2013 through 2015 reports included, in addition to the overall examination pass rate and the overall competency scores, the scores on five competencies: 1) Patient history, 2) Common neurological disorders, 3) Patient preparation and care, 4) Basic EEG concepts, and 5) Instrumentation. This change required additional analysis of variances of pass rate and overall score to determine if there is a difference in the means between examination version one (2010 through 2012), and version two (2013 through 2015).

General population

The initial analysis included all the candidates who sat for the EEG1 examinations administered from 2010 through 2015. There were 16 instances of the examination during that period. In total, 3087 candidates took the examination, 1984 were classified as first-time candidates, and 1103 were repeat-candidates. Repeat candidates are those who have attempted the examination one or more times in the past. The average pass rate was 50.21%, and the average score was 69.88%.

Table 11

EEG1 Examination 2010 – 2015

year	Exam Version	Pass	Fail	Total Candidates	Pass Rate %	Mean Score	SD	Mean Score %
2010	1	101	120	221	45.70	170.93	26.21	68.37
2010	1	91	126	217	41.94	169.62	23.88	67.85
2011	1	150	156	306	49.02	173.75	28.58	69.50
2011	1	180	268	448	40.18	163.62	32.52	65.45
2012	1	67	105	172	38.95	169.54	26.92	67.82
2012	1	47	77	124	37.90	163.53	26.36	65.41
2013	2	92	44	136	67.65	147.54	20.45	73.77
2013	2	123	67	190	64.74	146.77	18.16	73.39
2013	2	71	42	113	62.83	144.72	19.02	72.36
2013	2	99	70	169	58.58	144.11	21.76	72.06

Table Continues

Table 11

year	Exam Version	Pass	Fail	Total Candidates	Pass Rate %	Mean Score	SD	Mean Score %
2014	2	49	34	83	59.04	143.72	21.00	71.86
2014	2	103	86	189	54.50	141.46	22.39	70.73
2014	2	81	66	147	55.10	140.71	19.22	70.36
2015	2	69	75	144	47.92	138.44	22.36	69.22
2015	2	100	93	193	51.81	140.59	19.45	70.30
2015	2	127	108	235	54.04	139.36	21.48	69.68
Total		**1,550**	**1,537**	**3,087**	**50.21**			**69.88**

Categorization.

Guided by the theorized relationship between competence, level of education, and relevant work experience, the reported data are presented in two major categories: 1) highest level of education, and 2) number of years of experience. Out of the 3087 candidates, 2937 were classified into the designated categories under the level of education (Table 12), and 2791 were classified into the designated categories under work experience (Table 13) the remaining candidates were categorized as other and were not included in the analysis.

Table 12

Number of Candidates and Performance Categorized by Education

Year	Exam Sequence	Pass	Fail	Total	Pass Rate %	Mean Score %
2010	1	96	114	210	45.71	70.17
2010	2	87	122	209	41.63	68.50
2011	3	145	145	290	50.00	70.67
2011	4	169	255	424	39.86	67.67
2012	5	64	99	163	39.26	70.83
2012	6	43	74	117	36.75	63.00
2013	7	90	43	133	67.67	76.17
2013	8	120	65	185	64.86	76.33
2013	9	69	42	111	62.16	74.00
2013	10	97	65	162	59.88	72.50
2014	11	45	34	79	56.96	71.40
2014	12	96	81	177	54.24	71.80
2014	13	79	61	140	56.43	70.50

Table Continues

Table 12

Year	Exam Sequence	Pass	Fail	Total	Pass Rate %	Mean Score %
2015	14	64	68	132	48.48	65.50
2015	15	93	88	181	51.38	70.83
2015	16	124	100	224	55.36	72.17
Grand Total		**1481**	**1456**	**2937**	**50.43**	**70.75**

Table 13

Number of Candidates and Performance Categorized by Experience

Year	Exam Sequence	Pass	Fail	Total	Pass Rate %	Mean Score %
2010	1	72	111	183	39.34	68.00
2010	2	79	116	195	40.51	67.80
2011	3	110	143	253	43.48	69.40
2011	4	145	265	410	35.37	66.60
2012	5	47	100	147	31.97	66.60
2012	6	39	73	112	34.82	66.20
2013	7	86	64	150	57.33	76.80
2013	8	114	63	177	64.41	73.00
2013	9	68	41	109	62.39	72.60
2013	10	89	68	157	56.69	71.40
2014	11	44	34	78	56.41	70.80
2014	12	90	76	166	54.22	70.20
2014	13	78	64	142	54.93	70.00
2015	14	57	72	129	44.19	67.00
2015	15	81	81	162	50.00	69.60
2015	16	117	104	221	52.94	69.00
Grand Total		**1316**	**1475**	**2791**	**47.15**	**69.69**

Exclusions.

In addition to excluding the uncategorized scores from the data analysis, some categorized scores are also excluded from the analysis. Initial multivariate analysis of the available data using SPSS' MANOVA revealed that there is a statistically significant difference in the examination pass rates and the average examination scores between the groups with various educational levels. However, post hoc testing using Tukey HSD produced inconsistent results and indicated the Type I error levels are not guaranteed. Further examination of the available data revealed that the total number of candidates who were classified under GED, masters, and doctorate subcategories of the educational background are significantly lower than those under high school, associate degree, and bachelor's degree (Table 14). The small sample size of each of those three categories compared to the other three categories can cause this Type I error. Therefore, the scores associated with those subcategories were excluded from the analysis. Table 15 shows the number of candidates in each examination instance categorized by work experience.

Table 14

Number of Candidates in Education Subcategories

Education Level	Pass	Fail	Total	Pass Rate %	Mean Score %
GED*	46	67	113	40.71	67.81
High School	394	530	924	42.64	67.88
Associate Degree	517	619	1136	45.51	68.88
Undergraduate	438	203	641	68.33	74.19
Grad-M*	61	26	87	70.11	71.94
Grad-D*	25	11	36	69.44	74.14
Grand Total	**1481**	**1456**	**2937**	**50.43**	**70.81**

∗ Excluded from further data analysis

Table 15

Number of Candidates in Work Experience Subcategories

Level of Experience	Pass	Fail	Total	Pass Rate %	Mean Score %
< 1 Year	256	117	373	68.63	74.63
1 - 2 Yrs	414	310	724	57.18	71.44
3 -5 Yrs	331	511	842	39.31	67.31
6 - 10 Yrs	160	272	432	37.04	67.06
> 10 Yrs	155	265	420	36.90	68.00
Grand Total	**1316**	**1475**	**2791**	**47.15**	**69.69**

Examination version

A comparison of means (One-Way ANOVA) was completed, using *SPSS® Statistics 25*, to determine the effect of the examination version on the pass rate and mean score. Of the 128 scores, 48 were categorized as version one and 80 were version two. The mean pass rate for version one is 43.76% with standard deviation of 16.60 and 54.95% with standard deviation of 14.78 for version two. The mean examination score for version one was 67.75% with standard deviation of 3.90 and 71.22% with standard deviation of 4.08 for version two. The Levene Test for the Equality of Error Variances indicated a non-significant *p*-value (p =.231) between the two groups for the pass rate. It also indicated a non-significant *p*-value (p =.582) between the two groups for the scores. These results indicate that the variance across the two exam versions was not statistically different for the pass rate and score. Therefore, the assumption of homogeneity of variances was met for each group. The One-Way ANOVA (Table 16) revealed a significant effect of examination version on pass rates at $p < .05$ for the two versions $F(1, 126) = 15.66$, $p < .001$, and a significant effect of examination version on mean scores at $p < .05$ for the two versions $F(1, 126) = 22.52$, $p < .001$.

Table 16

ANOVA for Mean Differences by Examination Version

Factor		*Sum of Squares*	*df*	*Mean Square*	*F*	*p*
Pass Rate	Between Groups	.375	1	.375	15.656	.000
	Within Groups	3.022	126	.024		
	Total	3.397	127			
Average Exam Score	Between Groups	.036	1	.036	22.519	.000
	Within Groups	.203	126	.002		
	Total	.239	127			

Conclusion.

These results suggest that there is a statistically significant improvement in the second version of the examinations' pass rate (mean difference = 11.19%) as well as the mean examinations' score (mean difference = 3.74%) when compared to the first version.

The following presentation of results is based on the findings of the examination versions' differences as well as the distinction between the two major categories: highest educational level achieved and the number of years of experience in the field at the time of the examination.

Multivariate Analysis

The examination data were analyzed based on two primary categories and multiple subcategories for each examination version. Table 17 presents the organization of the data analysis.

Table 17

Frequency and number of scores for each subcategory

Background Category	Exam Version	Background Level	Number of examination Instances	Number of scores (candidates)
Highest level of education	1	High School	6	521
		Associate Degree	6	536
		Bachelor's Degree	6	240
	2	High School	10	403
		Associate Degree	10	600
		Bachelor's Degree	10	401
Previous Work Experience	1	< 1 Yr.	6	93
		1-2 Yrs.	6	229
		3-5 Yrs.	6	490
		6-10 Yrs.	6	239
		> 10 Yrs.	6	249
	2	< 1 Yr.	10	280
		1-2 Yrs.	10	495
		3-5 Yrs.	10	352
		6-10 Yrs.	10	193
		> 10 Yrs.	10	171

Multivariate Analysis of Variances (MANOVA) was performed to test the hypotheses of this study. MANOVA is the preferred method for testing hypotheses when the data contain one or more categorical independent variables with two or more treatment levels (Background Level) and more than one continuous response variable (Examination Pass Rate and Average Score). Before performing the MANOVA, a series of four Pearson correlation tests were conducted. Pearson correlations, Tables 18 – 21, show meaningful correlations between each of the background categories for both versions of the examination and the examination pass rate and average score at $p<.001$ level. One-way MANOVA tests were then performed to test the two hypotheses. Hypothesis one states that there is a statistically significant difference in the examination pass rate and average score between educational levels (HS, AS, and BS). Hypothesis two states that there is a statistically significant difference in the examination pass rate and average score between work experience levels (< 1 yr., 1-2 yrs., 3-5 yrs., 6-10 yrs., and > 10 yrs.). A statistically significant difference was found for each level. Following the MANOVA, a series of one-way ANOVAs on each of the dependent variables was conducted. Finally, a series of post-hoc analysis (Tukey's HSD) was conducted to examine individual mean difference comparisons across all subcategories of the background levels.

Pearson Correlations.

Tables 18 through 21 show the correlation between educational background, work experience, examination pass rate, and average examination score for each version of the examination.

Table 18

Education, Exam Version 1

Parameter	Pass Rate	Average Exam Score	Education
Pass Rate	1		
Average Exam Score	0.935*	1	
Education	0.759*	0.783*	1

*. Correlation is significant at the 0.01 level (2-tailed).

Table 19

Education, Exam Version 2

Parameter	Pass Rate	Average Exam Score	Education
Pass Rate	1		
Average Exam Score	0.934*	1	
Education	0.738*	0.763*	1

*. Correlation is significant at the 0.01 level (2-tailed).

Table 20

Work Experience, Exam Version 1

Parameter	Pass Rate	Average Exam Score	EXP
Pass Rate	1		
Average Exam Score	0.941*	1	
EXP	-0.779*	-0.784*	1

*. Correlation is significant at the 0.01 level (2-tailed).

Table 21

Work Experience, Exam Version 2

Parameter	Pass Rate	Average Exam Score	EXP
Pass Rate	1		
Average Exam Score	0.648*	1	
EXP	-0.559*	-0.47*	1

*. Correlation is significant at the 0.01 level (2-tailed).

Education level

ANOVA tests revealed that there was a statistically significant difference between examination version one and examination version two overall, and for each factor: educational background and work experience.

Examination version one.

Table 22

Descriptive Statistics: Highest Educational Level, Exam Version One

	Background Level	Mean	Std. Deviation	N
Average Exam Score	HS	.658	.0194	6
	Associate Degree	.665	.0122	6
	Bachelor's Degree	.725	.0243	6
Pass Rate	HS	.385	.0623	6
	Associate Degree	.368	.0565	6
	Bachelor's Degree	.622	.0538	6

A one-way MANOVA was performed for the group of scores based on the educational background for version one of the examination. A statistically significant MANOVA was obtained, Pillai's Trace = .96, $F(4, 30) = 6.98$, $p < .001$. The multivariate effect size estimated at .482, which implies that, for examination version one, 48.2% of the variability in the average examination score can be accounted for by the educational level. Additionally, Box's test of equality of covariance returned a nonsignificant value Box's M = 6.00, $p = .565$ which implies that the observed covariance matrices of the dependent variables are equal across groups. Levene's Test for the Equality of Error Variances returned a nonsignificant Levene statistic $F(2,15) = 1.997$, $p = .170$ between the groups for the pass rate as well as a non-significant Levene statistic $F(2,15) = 1.811$, $p = .729$ between the groups for the scores. These results imply that the variances across the three-educational sublevels were not statistically different for the pass rate and score

(Table 23); therefore; the assumption of homogeneity of variances was met for this MANOVA.

Table 23

Levene's Test of Equality of Error Variances [a,b]

		Levene Statistic	df1	df2	Sig.
Average Exam Score	Based on Mean	1.997	2	15	.170
Pass Rate	Based on Mean	1.811	2	15	.729

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Background Category = Highest Educational Level, Exam Version = Exam Version 1
b. Design: Intercept + Background Level

ANOVA Results. Following the MANOVA, a series of one-way ANOVAs were conducted followed by post-hoc analysis. For the educational background, exam version one group, ANOVA was significant at $p = .05$ for both dependent variables. Homogeneity tests returned a nonsignificant Levene at $p = .05$ in both cases. Tests of Between-Subjects Effects were significant with effect size (partial $\eta 2$) of .829 for pass rate and average examination score with observed power of 1.00 using alpha = 0.05 for both dependent variables.

Conclusion. Multiple comparisons between the three levels of education (HS, AS, and BS) were performed. The comparison results revealed that, for this group (Background = Education, Examination version one), on average, candidates with undergraduate degrees had higher pass rate and average exam scores than those with associate degrees and high school diplomas. There was no statistically significant difference in the examination pass rates and average scores between candidates with associate degrees and high school diplomas.

Table 24

Multiple Comparisons Tukey HSD (Educational Levels, Exam Version One)

Dependent Variable:		Pass Rate		Average Exam Score	
Highest Educational Level		Mean Difference	Sig.	Mean Difference	Sig.
HS	Associate Degree	0.0172	0.865	-0.0067	0.823
	Bachelor's Degree	-.2365*	0.000	-.0667*	0.000
Associate Degree	HS	-0.0172	0.865	0.0067	0.823
	Bachelor's Degree	-.2536*	0.000	-.0600*	0.000
Bachelor's Degree	HS	.2365*	0.000	.0667*	0.000
	Associate Degree	.2536*	0.000	.0600*	0.000

Based on observed means.
The error term is Mean Square(Error) = .000.
*. The mean difference is significant at the .05 level.

Examination version Two.

Descriptive statistics. Table 25 lists the descriptive statistics for the group categorized by highest educational level and examination version two.

Table 25

Descriptive Statistics: Highest Educational Level, Exam Version Two

	Background Level	Mean	Std. Deviation	N
Average Exam Score	HS	.691	.0185	10
	Associate Degree	.703	.0195	10
	Bachelor's Degree	.752	.0225	10
Pass Rate	HS	.476	.1040	10
	Associate Degree	.534	.0772	10
	Bachelor's Degree	.712	.0803	10

A one-way MANOVA was performed for the group of scores based on the educational background for version two of the examination. A statistically significant MANOVA was obtained, Pillai’s Trace = .67, $F(4, 54) = 6.75$, $p < .001$. The multivariate effect size estimated at .333, which implies that, for examination version one, 33.3% of the variability in the average examination score can be accounted for by the educational level. Additionally, Box's test of equality of covariance returned a nonsignificant value Box's M = 5.55, p = .550 which implies that the observed covariance matrices of the dependent variables were equal across groups. Levene's Test for the Equality of Error Variances returned a nonsignificant Levene statistic $F(2,27) = .044$, p =.957 between the groups for the pass rate as well as a non-significant Levene statistic $F(2,27) = .492$, p =.617 between the groups for the scores. These results imply that the variances across the three-educational sublevels were not statistically different for the pass rate and score (Table 26). Therefore, the assumption of homogeneity of variances was met for this MANOVA.

Table 26

Levene's Test of Equality of Error Variances [a,b]

		Levene Statistic	df1	df2	Sig.
Average Exam Score	Based on Mean	.492	2	27	.617
Pass Rate	Based on Mean	.044	2	27	.957

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Background Category = Highest Educational Level, Exam Version = Exam Version 2
b. Design: Intercept + Background Level

ANOVA Results. Following the MANOVA, a series of one-way ANOVAs were conducted followed by post-hoc analysis. For the educational background, exam version two group, ANOVA was significant at p = .05 for both dependent variables. Homogeneity tests returned a nonsignificant Levene at p = .05 in both cases. Tests of Between-Subjects Effects were significant with effect size (partial η2) of .593 for pass rate and .654 for average examination score. These results imply that, for examination version two, 59.3% of the variability in examination pass rate and 65.4% of the variability in the average examination score was accounted for by the educational background.

Conclusion. Following the multiple comparisons between the three levels of education (HS, AS, and BS), the results revealed that for this group (Background = Education, Examination version two), on average, candidates with undergraduate degrees had higher pass rate and average exam scores than those with associate degrees and high school diplomas (Table 27). There was no statistically significant difference in the examination pass rates and average scores between candidates with associate degrees and high school diplomas.

Table 27

Multiple Comparisons Tukey HSD (Educational levels, Exam Version Two)

Dependent Variable:		Pass Rate		Average Exam Score	
Highest Educational Level		Mean Difference	Sig.	Mean Difference	Sig.
HS	Associate Degree	.0172	.865	-.0120	.394
	Bachelor's Degree	-.2365*	.000	-.0610*	.000
Associate Degree	HS	-.0172	.865	.0120	.394
	Bachelor's Degree	-.2536*	.000	-.0490*	.000
Bachelor's Degree	HS	.2365*	.000	.0610*	.000
	Associate Degree	.2536*	.000	.0490*	.000

Based on observed means.
The error term is Mean Square(Error) = .000.
*. The mean difference is significant at the .05 level.

Conclusion.

Given the results obtained following the statistical analysis of examination pass rates and average scores for the educational background under both examination versions, on average, the candidates with postsecondary education (undergraduate degrees) had higher pass rates and average examination scores than those with associate degrees or high school diplomas. There was no statistically significant difference in the pass rate or the average scores between candidates with associate degrees and those with high school diplomas. Furthermore, on average, for examination version two, the examination pass rates and average scores were higher than those for examination version one across all educational levels analyzed (Figure 5)

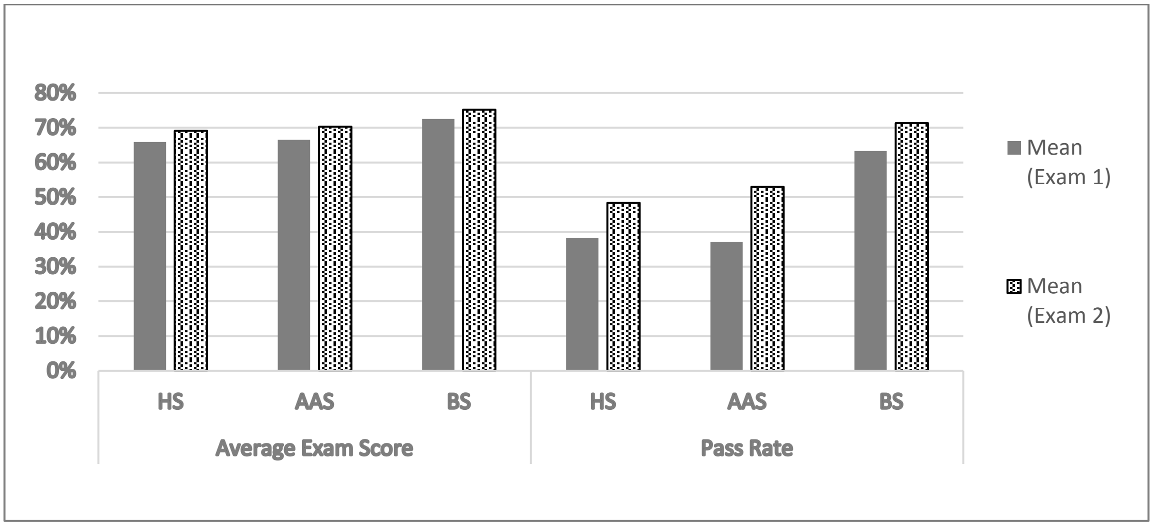

Figure 5. Average Examination Scores and Pass Rates for Examination Version one and two

Work Experience

Examination version one.

Descriptive statistics. Table 28 lists the descriptive statistics for the group categorized by the number of years of experience, and examination version one.

Table 28

Descriptive Statistics: Number of Years of Experience, Exam Version One

	Background Level	Mean	Std. Deviation	N
Average Exam Score	< 1 Yr.	.7283	.0147	6
	1-2 Yrs.	.7067	.0175	6
	3-5 Yrs.	.6467	.0151	6
	6-10 Yrs.	.6400	.0253	6
	> 10 Yrs.	.6500	.0237	6
Pass Rate	< 1 Yr.	.6703	.1415	6
	1-2 Yrs.	.5597	.0819	6
	3-5 Yrs.	.3074	.0681	6
	6-10 Yrs.	.2798	.0712	6
	> 10 Yrs.	.3092	.1001	6

A one-way MANOVA was performed for the group of scores based on related work experience background for version one of the examination. A statistically significant MANOVA was obtained, Pillai's Trace = .82, $F(8, 50) = 4.36$, $p < .001$. The multivariate effect size was estimated at .411, which implies that, for examination version one, 41.1% of the variability in the average examination score can be accounted for by the work experience level. Additionally, Box's test of equality of covariance returned a nonsignificant value Box's M = 12.79, $p = .569$ which implies that the observed covariance matrices of the dependent variables were equal across groups. Levene's Test for the Equality of Error Variances returned a nonsignificant Levene statistic $F(4,25) = 1.433$, $p = .252$ between the groups for the pass rate as well as a non-significant Levene statistic $F(4,25) = 1.324$, $p = .268$ between the groups for the scores. These results imply that the variances across the five-work experience sublevel were not statistically different for the pass rate and score (Table 29). Therefore, the assumption of homogeneity of variances was met for this MANOVA.

Table 29

Levene's Test of Equality of Error Variances [a,b]

		Levene Statistic	df1	df2	Sig.
Average Exam Score	Based on Mean	1.324	4	25	.289
Pass Rate	Based on Mean	1.433	4	25	.252

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Background Category = Work Experience Level, Exam Version = Exam Version 1
b. Design: Intercept + Background Level

ANOVA Results. Following the MANOVA, a series of one-way ANOVAs were conducted followed by post-hoc analysis. For the work experience level, exam version one group, ANOVA was significant at $p = .05$ for both dependent variables.

Homogeneity tests returned a nonsignificant Levene statistic at $p = .05$ in both cases. Tests of Between-Subjects Effects were significant with an effect size (partial η2) of .766 for pass rate and .800 for average examination score with an observed power of 1.00 using alpha = 0.05 for both dependent variables. These results indicate that 76.6% of the variation in pass rate and 80.0% of the variation in examination scores (dependent variables) was accounted for by the variation in the work experience level (independent variable).

Conclusion. Multiple comparisons between the five levels of work experience (<1 Yr., 1-2 Yrs., 3-5 Yrs., 6-10 Yrs., > 10 Yrs.) were performed using Tukey HSD post-hoc test (Table 30). Surprisingly, the results revealed that for this group (Background = work experience, Examination = version one), on average, candidates with a lesser number of years of experience had higher pass rates and average exam scores than those with more years of experience. There was no statistically significant difference in the examination pass rates and average scores between candidates' groups with less than one year and one to two years of experience; as well as no statistically significant difference between groups with more than three years of experience (Tables 31 and 32).

Table 30

Multiple Comparisons Tukey HSD (Work Experience, Exam Version One)

Dependent Variable:		Pass Rate		Average Exam Score	
Work Experience		Mean Difference	Sig.	Mean Difference	Sig.
< 1 Yr.	1-2 Yrs.	.111	.301	.022	.343
	3-5 Yrs.	.363*	.000	.082*	.000
	6-10 Yrs.	.390*	.000	.088*	.000
	> 10 Yrs.	.361*	.000	.078*	.000
1-2 Yrs.	< 1 Yr.	-.111	.301	-.022	.343
	3-5 Yrs.	.252*	.001	.060*	.000

Table continues

Table 30

Dependent Variable:		Pass Rate		Average Exam Score	
Work Experience		Mean Difference	Sig.	Mean Difference	Sig.
	6-10 Yrs.	.280*	.000	.067*	.000
	> 10 Yrs.	.250*	.001	.057*	.000
3-5 Yrs.	< 1 Yr.	-.363*	.000	-.082*	.000
	1-2 Yrs.	-.252*	.001	-.060*	.000
	6-10 Yrs.	.028	.987	.007	.976
	> 10 Yrs.	-.002	1.000	-.003	.998
6-10 Yrs.	< 1 Yr.	-.390*	.000	-.088*	.000
	1-2 Yrs.	-.280*	.000	-.067*	.000
	3-5 Yrs.	-.028	.987	-.007	.976
	> 10 Yrs.	-.029	.983	-.010	.903
> 10 Yrs.	< 1 Yr.	-.361*	.000	-.078*	.000
	1-2 Yrs.	-.250*	.001	-.057*	.000
	3-5 Yrs.	.002	1.000	.003	.998
	6-10 Yrs.	.029	.983	.010	.903

Based on observed means. The error term is Mean Square(Error) = .000.

*. The mean difference is significant at the .05 level.

Table 31

Tukey HSD[b,c] , Pass Rate[a]

Background Level	N	Subset	
		1	2
6-10 Yrs.	6	0.280	
3-5 Yrs.	6	0.307	
> 10 Yrs.	6	0.309	
1-2 Yrs.	6		0.560
< 1 Yr.	6		0.670
Sig.		0.983	0.301

Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square(Error) = .009.

a. Exam Version = Exam Version 1

b. Uses Harmonic Mean Sample Size = 6.000.

c. Alpha = .05.

Table 32

Tukey HSD[b,c] , Average Examination Score[a]

Background Level	N	Subset	
		1	2
6-10 Yrs.	6	0.640	
3-5 Yrs.	6	0.647	
> 10 Yrs.	6	0.650	
1-2 Yrs.	6		0.707
< 1 Yr.	6		0.728
Sig.		0.903	0.343

Means for groups in homogeneous subsets are displayed. Based on observed means. The error term is Mean Square(Error) = .009.
a. Exam Version = Exam Version 1

b. Uses Harmonic Mean Sample Size = 6.000.

c. Alpha = .05.

Examination version Two.

Table 33

Descriptive Statistics: Highest Educational Level, Exam Version Two

	Background Level	Mean	Std. Deviation	N
Average Exam Score	< 1 Yr.	.7570	.0600	10
	1-2 Yrs.	.7190	.0129	10
	3-5 Yrs.	.6890	.0354	10
	6-10 Yrs.	.6890	.0197	10
	> 10 Yrs.	.6980	.0437	10
Pass Rate	< 1 Yr.	.6874	.1355	10
	1-2 Yrs.	.5789	.0437	10
	3-5 Yrs.	.5078	.1124	10
	6-10 Yrs.	.4556	.1254	10
	> 10 Yrs.	.4448	.1954	10

A one-way MANOVA was performed for the group of scores based on work experience background for version two of the examination. A statistically significant MANOVA was obtained, Pillai's Trace = .45, $F(8, 90) = 3.31$, $p = .002$. The multivariate effect size was estimated at .227, which implies that, for examination version one, 22.7% of the variability in the average examination score can be accounted for by the work experience level. Box's test of equality of covariance returned a significant value Box's M = 64.00, $p < .001$ which implies that the observed covariance matrices of the dependent variables are not equal across groups. Additionally, Levene's Test for the Equality of Error Variances returned a significant Levene statistic $F(4,45) = 2.834$, $p = .035$ between the groups for the pass rate and a nonsignificant Levene statistic $F(4,45) = .492$, $p = .131$ between the groups for the average examination scores (Table 34). These results imply that the assumption of homogeneity of variances was not met for this MANOVA and we will have to account for that during the follow-up ANOVA tests and the post-hoc testing.

Table 34

Levene's Test of Equality of Error Variances [a]

		Levene Statistic	df1	df2	Sig.
Average Exam Score	Based on Mean	1.880	4	45	.131
Pass Rate	Based on Mean	2.834	4	45	.035

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Background Category = Work Experience Level, Exam Version = Exam Version 2

ANOVA Results. Following the MANOVA, a series of one-way ANOVAs were conducted followed by post-hoc analysis. For the group of work experience level and exam version two, ANOVA was significant $F(4,45) = 5.67$, $p = .001$ for the average examination score dependent variable. Homogeneity test returned a nonsignificant Levene statistic at $p = .131$. Tests of Between-Subjects Effects were significant with an effect size (partial $\eta 2$) of .335 for average examination score. These results imply that, for examination version two, 33.5% of the variability in the average examination score was accounted for by the work experience level. With the examination pass rate as the dependent variable, the second ANOVA test was significant $F(4,45) = 5.807$, $p = .001$.

Tests of Between-Subjects Effects were significant with an effect size (partial $\eta 2$) of .340 for the examination pass rate. These results imply that, for examination version two, 34.0% of the variability in the examination pass rate was accounted for by the work experience level. Homogeneity test returned a significant Levene statistic at p = .036, which suggests that the equal variances assumption is violated. ANOVA is robust to this violation when the groups are of equal or near equal size. Therefore, it is recommended that a Games-Howell post-hoc test be used instead of Tukey's HSD.

Conclusion. Multiple comparisons between the five levels of work experience (< 1 Yr., 1-2 Yrs., 3-5 Yrs., 6-10 Yrs., > 10 Yrs.) were performed. The results revealed that for this group (Background = Work Experience, Examination Version = two), on average, candidates with a lower number of years of experience have higher pass rates and average exam scores than those with more years of experience (Table 35).

Table 35

Multiple Comparisons (Work Experience, Exam Version Two)

Dependent Variable:		Pass Rate (Tukey HSD)		Average Exam Score (Games-Howell)	
Highest Educational Level		Mean Difference	Sig.	Mean Difference	Sig.
< 1 Yr.	1-2 Yrs.	.1085	.363	.0380	.351
	3-5 Yrs.	.1796*	.030	.0680	.051
	6-10 Yrs.	.2318*	.003	.0680	.038
	> 10 Yrs.	.2425*	.001	.0590	.135
1-2 Yrs.	< 1 Yr.	-.1085	.363	-.0380	.351
	3-5 Yrs.	.0711	.748	.0300	.154
	6-10 Yrs.	.1233	.241	.0300*	.008
	> 10 Yrs.	.1341	.172	.0210	.607
3-5 Yrs.	< 1 Yr.	-.1796*	.030	-.0680	.051
	1-2 Yrs.	-.0711	.748	-.0300	.154
	6-10 Yrs.	.0522	.901	.0000	1.000
	> 10 Yrs.	.0630	.821	-.0090	.986

Table continues

Table 35

Dependent Variable:		Pass Rate (Tukey HSD)		Average Exam Score (Games-Howell)	
6-10 Yrs.	< 1 Yr.	-.2318*	.003	-.0680*	.038
	1-2 Yrs.	-.1233	.241	-.0300*	.008
	3-5 Yrs.	-.0522	.901	.0000	1.000
	> 10 Yrs.	.0108	1.000	-.0090	.973
> 10 Yrs.	< 1 Yr.	-.2425*	.001	-.0590	.135
	1-2 Yrs.	-.1341	.172	-.0210	.607
	3-5 Yrs.	-.0630	.821	.0090	.986
	6-10 Yrs.	-.0108	1.000	.0090	.973

Based on observed means.
The error term is Mean Square(Error) = .000.
*. The mean difference is significant at the .05 level.

Conclusion.

Surprisingly, given the results obtained following the statistical analysis of examination pass rates and average scores for the work experience level for both examination versions, on average, candidates with fewer years of work experience had higher pass rate and average examination scores than those with more years of work experience. Post-hoc analysis revealed two homogenous subsets within the sample data based on work experience levels; subset one included groups with less than three years of experience and subset two included groups with more than three years of experience. Furthermore, on average, for examination version two, the examination pass rates and average scores were higher than those for examination version one across groups in subset two of experience levels (Figure 6).

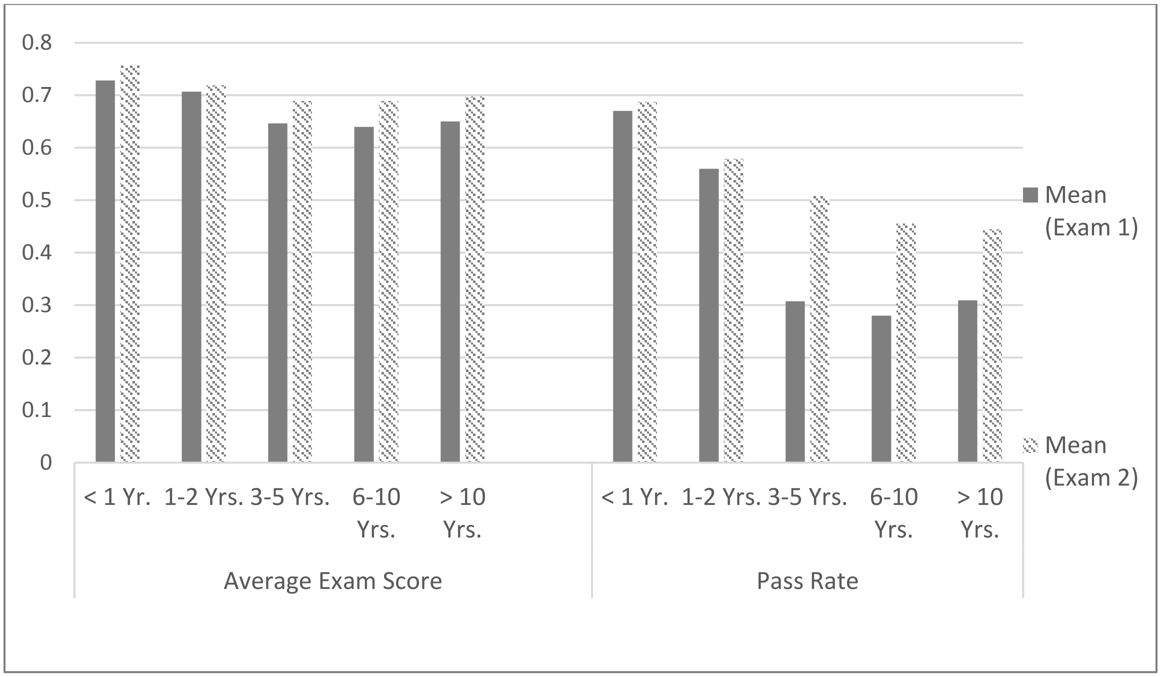

Figure 6. Mean Examination Score and Pass Rate

Summary

The purpose of this analysis was to examine the effects of education and work experience on the ABRET EEG1 examination results. A combination of one-way ANOVA and MANOVA tests were used for that purpose. The data extracted from the available examinations reports were divided into two major categories based on the change in the examination structure in 2013. Furthermore, two subcategories of scores were identified under each examination version: 1) Highest educational level attained by candidates, and 2) Number of years of relevant work experience at the time of the examination. The initial one-way MANOVA test, using examination version as the independent variable and examination pass rates and average scores as the dependent variables, indicated that there was a statistically significant difference between the results of the two examination versions. This justified treating each examination version as an independent group. Secondary analysis using the same methods also indicated that on average examination pass rates and average scores were higher for examination version two when compared to those of examination version one. Further testing also indicated that the mean averages of pass rate and scores increased with the increase in the level of education. Surprisingly, this relationship was reversed for the number of years of relevant work experience.

For the past few years, neurodiagnostic professional societies have been calling for an increase in the number of educational programs for ND technologists. The following chapter includes more detailed discussion of the results and their implications on the neurodiagnostic technologists' community and their efforts to improve the overall education of the ND technologists.

Chapter V

Discussion

Introduction

The purpose of this study was to examine the effects of education and previous work experience on the competency of neurodiagnostic technologists (ND techs) as measured by the American Board of Registered Electroneurodiagnostic Technologists (ABRET). Although postsecondary education is not currently required to sit for any of the examinations offered by ABRET, many ND techs, when the choice is available, choose to join a formal training program at a local community college or private institution. As evident by the small number of educational programs, the development of neurodiagnostic educational programs in the United States of America, and around the world, has been slow (CAAHEP, 2015).

The scarcity of ND techs and the high demand for well-trained technologists attract individuals with diverse educational backgrounds to this field. Therefore, theoretically, examining the effect of educational level of examinees (micro-systems) is essential to the studying of ND education in general (macro-system). The General System Theory explains the inter-relationships of the micro-systems and their dynamic relationship to the macro-system (von Bertalanffy, 1950). The overall macro system of allied health education is a function of its microsystems: competency and behavior. While playing an important role in shaping the bigger picture, each microsystem is also a function of smaller systems. Additionally, the interdependency between systems is also an important feature of this theory. Within the macro system, each microsystem seeks to reach a state of equilibrium, and in-turn influences the equilibrium of other microsystems and the whole macro system as shown in Figure 7 below.

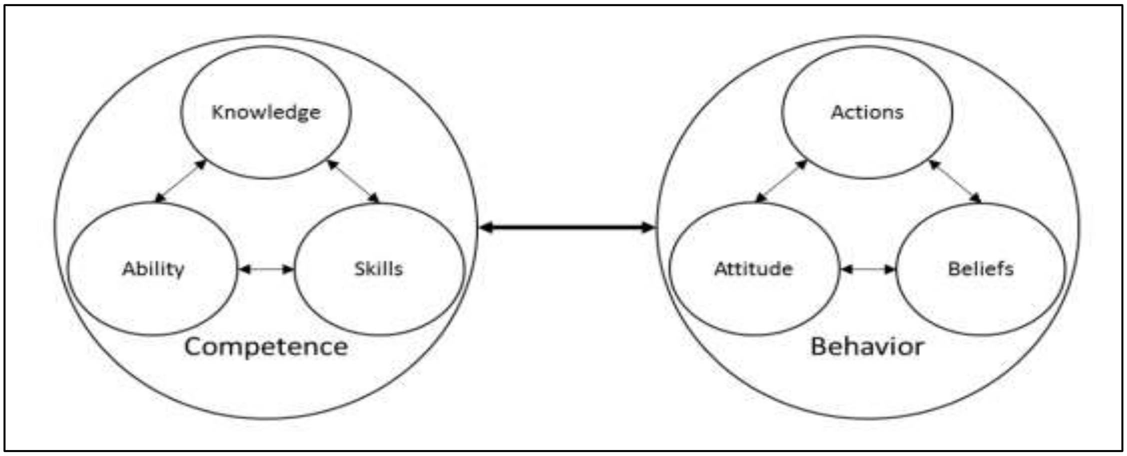

Figure 7. Allied Health Education System

The General Systems Theory provides the bases for understanding the intricate relationships within the allied health education's environment. The individual factors: knowledge, skills, and abilities constitute the competency system. Work experience builds technical skills and abilities. Thus, we may conceptualize competence (C) in allied health as a function (f) of education (e) and experience (x); $C = f(e, x)$.

The level of vocational competence most probably involves a definable explicit interaction between experiential learning and didactic instructions. Within this context, the level of experiential learning level can be further defined as the summation of tasks performed under supervision times the length of time (τ) spent on each task (T): $\chi = \sum(\tau \times \mathrm{T})$. For every occupational role, a defined and measurable competency exists and is influenced by the level of on-the-Job / Vocational training received. The level of education achieved by each individual within that field and the level of experience influences that level of competence (Figure 8). Within this relationship, we hypothesized a positive correlation between the level of education and competence. Therefore, as the level of education increases, we would expect to see a positive change in the measurement of competence within the profession. This study found a statistically significant correlation between the level of education and competence. Moreover, for each profession, a validated process, an examination, determines the level of competence. The examination pass rates and average examination scores were used to determine the ND technologists' level of competence. In addition, the Level of Experience contributes to the level of competence. Therefore, we also postulate that the level of experience influences the level of competence. The negative correlation between the level of experience and the level of competence was surprising. However, the hyopthesized formula defining that relationship holds true: there exists some interaction between the level of experience and the competency of ND technologists as measured by the examination pass rates and average examination scores.

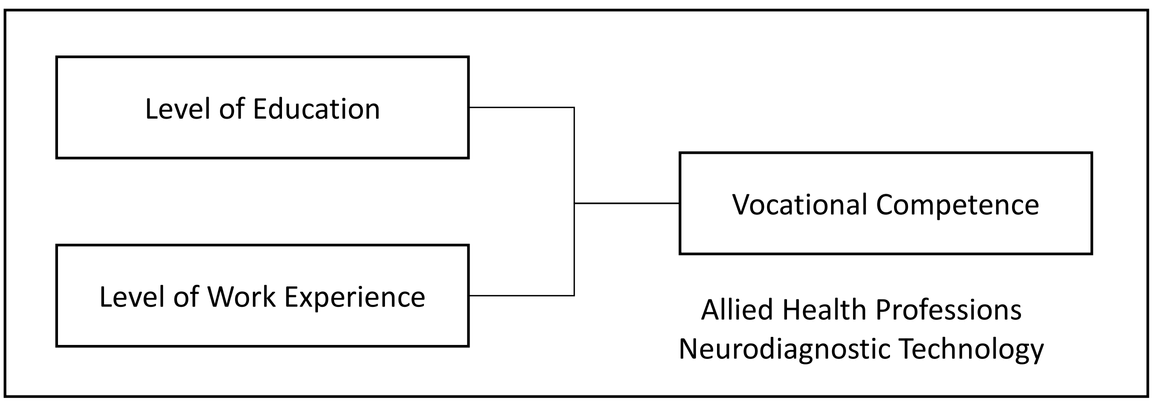

Figure 8. Study *Theoretical Model*

Examination

In 2013, ABRET started a new format of the EEG1 examination. The new format differed from the older version of the examination in two ways: 1) The total number of questions was reduced from 250 to 200 questions, and 2) The examination focused on five competency areas instead of the four areas in the previous version. Although there was no significant change in the overall educational background of the candidates for the three-year period following the examination change when compared to the three-year period before the change, the examination pass rate improved by 14 percentage points. This improvement may have been influenced by the extensive job analysis that was performed by ABRET which may have led to increased focus on job-related competency measures. The data analysis also showed a statistically significant difference between groups of candidates in version one and version two across educational background as well as across work experience categorizations. In general, candidates across all groups performed better on examination version two when compared to version one. Nevertheless, the pass rate for the EEG1 examination remained in the 50 to 57% range, which is low compared to examination pass rates in other allied health professions.

Level of Education

Initial analysis of the data extracted from the examinations reports revealed a significant difference between the number of candidates in the various subcategories of educational level which increases the chances of type I error in ANOVA testing. Therefore, candidates in the GED, Masters, and Doctoral degrees were excluded from the secondary data analysis due to the small number of candidates in each of those categories when compared to the remaining categories (Table 36).

Table 36

Number of Candidates in Education Subcategories

Education Level	Pass	Fail	Total	Pass Rate %	Mean Score %
GED*	46	67	113*	40.71	67.81
High School	394	530	924	42.64	67.88
Associate Degree	517	619	1136	45.51	68.88
Undergraduate	438	203	641	68.33	74.19
Grad-M*	61	26	87*	70.11	71.94
Grad-D*	25	11	36*	69.44	74.14
Grand Total	**1481**	**1456**	**2937**	**50.43**	**70.81**

∗ Excluded from further data analysis

Study hypothesis one stated that there is no difference in the performance on ABRET examinations between candidates with various educational backgrounds. Data analysis revealed a statistically significant difference in the performance on ABRET's EEG1 examination between candidates with the various educational background for examination versions one and two. Therefore, the null hypothesis was rejected for the alternative. In general, the results show that candidates with a higher level of education have higher examination pass rate and higher average examination scores. So, candidates with bachelor's degrees performed better than those with associate degrees, and those with associate degrees performed somewhat comparable to those with high school diplomas. Furthermore, there were two additional significant findings: 1) There is a significant positive correlation between the candidates' level of education and the examination pass rate in both examination versions; and 2) There is a significant positive correlation between the candidates' level of education and the average examination scores in both examination versions. These results are consistent with the O'Daniel (1987) study of respiratory therapists pass rates and scaled score averages on the National Board for Respiratory Therapists national examination. O'Daniel reported that therapists with bachelor's degrees had higher examination pass rates and higher average scores when compared to graduates of an associate degree therapy program.

Work Experience

This study suggested that, in general, the level of experience contributes to the level of competence. Therefore, an increase in the level of experience may lead to an increase in the level of competence. Therefore, we hypothesized that there is a difference in the performance on ABRET examinations between candidates with various levels of related work experience. We used one-way MANOVA to test this hypothesis, and Tukey HSD and correlation analysis as follow up tests. Test results showed that there was a statistically significant difference between groups with different work experience levels on both the examination pass rates and the average examination scores. Therefore, these results supported rejecting the null hypothesis. The follow up testing revealed two surprising observations: 1) There is a statistically significant negative correlation between the examination pass rates and the number of years of related work experience; and 2) There is a statistically significant negative correlation between the average examination scores and the number of years of related work experience. Furthermore, post-hoc analysis revealed two homogenous subsets within the sample data based on work experience levels; subset one included groups with less than three years of experience and subset two included groups with more than three years of experience. Subset one scores and pass rate were higher than those for subset two. Additionally, on average, the examination pass rates and average scores are higher for examination version two when compared to those for examination version one across groups in subset two of experience levels. In general, the distribution of candidates over the various levels of work experience remained more-or-less the same over the periods before and after the change in the examination. Therefore, the improved performance on the examination may indicate that the new practice analysis may have led to a more accurate measurement of ND technologists' competence.

The negative correlation between competency scores and number of years of work experience could be attributed to multiple factors that were not part of the dataset available for this research. Factors such as, but not limited to, age, examination taking skills, acquisition of new and updated knowledge, amount of time dedicated to examination preparation, and previous performance on examinations could have a significant effect on examination performance. Andujar et al. (2010) reported that performance on the national ranking examination for medical students was strongly correlated with past performance on medical school examinations. Future research in this area could be helpful in identifying those relevant factors to neurodiagnostic technologists.

Limitations

The current study depended on archival data collected by ABRET and reported as part of the aggregate examination results reports. Consequently, the limited amount of data on examinations candidates limited the scope of the study. Although the total number of candidates was significant, the aggregate nature of the reports limited the ability to correlate work experience with the type of education each candidate received before taking the examination.

Professional implications and Recommendations for Future Research

Considering the significant shortage of highly skilled ND techs, the insufficient number of formal education programs to train and educate new technologists, and the positive correlation between education level and competency level of ND techs, the findings of this study could be a useful tool to encourage academic centers to create new bachelor's degree programs in neurodiagnostic technology. ASET's Board of Trustees has created a *Formal Education Task Force* to help encourage colleges and universities to develop undergraduate programs in neurodiagnostic technology. This study adds to the limited body of literature supporting the goals of this task force.

Future studies may further examine the effect of trainers' qualifications and their teaching methods on the quality of education as measured by examination success rate and average examination scores. Future research might also provide a closer examination of the effect of higher education on specific competencies measured by the examination and their relationship to practical clinical competencies.

Recommendations for Practice

The present study provides an analysis of the examination pass rate and average examination scores of ABRET's EEG one examination. The results show the effect of education and previous work experience on the clinical competence of ND technologists as measured by ABRET. The recommendations for practice based on the study findings are organized into two sections: 1) Level of Education; and 2) work experience.

Level of education. There are three recommendations:

1) It is recommended that universities with existing allied health programs start exploring the possibilities of adding a new undergraduate program for neurodiagnostic technology into their portfolio.
2) It is recommended that community colleges with an existing neurodiagnostic program start collaboration efforts with area universities to create a pathway to an undergraduate degree through a degree completion program. This model has a proven track record of success. For example, the University of Houston has an RN to BSN degree completion program for registered nurses with associate degrees.
3) The findings of this study also support the recommendation that management of healthcare institutions consider the level of education instead of seniority when identifying ND technologists for future leadership roles.

Work Experience. There are two recommendations:

1) It is recommended that existing training programs' leadership encourage their senior students and graduates to take the ABRET EEG1 examination as soon as they meet the requirements set forth by ABRET.
2) It is also recommended that the management of neurodiagnostic laboratories implement incentive programs to encourage their junior technologists to take the ABRET EEG1 examination as soon as they meet the eligibility criteria defined by ABRET.

Summary

Within the limits of the scope of this study, the analysis of examination data revealed three significant findings: 1) The change in examination format in 2013 resulted in a statistically significant increase in the examination pass rate and the average examination scores; 2) There is a significant positive correlation between level of education and neurodiagnostic technologists' competence as measured by the ABRET EEG1 examination; and 3) There is a negative correlation between the number of years of related work experience and ND technologists' competence as measured by the ABRET EEG1 examination. The implications of these findings are summarized in Table 37.

Table 37

Summary of Findings and Recommendations

Findings	Concerned Institution / Organization	Implication
The change in examination format in 2013 resulted in a statistically significant increase in the examination pass rate and the average examination scores;	ABRET	Continue the efforts started in 2013 with an extensive practice analysis to improve the reliability of ABRET examinations.
There is a significant positive correlation between the level of education and neurodiagnostic technologists' competence as measured by the ABRET EEG1 examination	Universities with existing allied health programs	Start exploring the possibilities of adding a new undergraduate program for neurodiagnostic technology into their portfolio
	Community Colleges with Existing ND Technology Programs	Start collaboration efforts with area universities to create a pathway to an undergraduate degree through a degree completion program
	Management of healthcare institutions	Management of healthcare institutions consider the level of education instead of seniority when identifying ND technologists for future leadership roles

Table continues

Table 37

Findings	Concerned Institution / Organization	Implication
There is a negative correlation between the number of years of related work experience and ND technologists' competence as measured by the ABRET EEG1 examination	The leadership of existing training programs	Encourage their senior students and graduates to take the ABRET EEG1 examination as soon as they meet the requirements setforth by ABRET
	Management of neurodiagnostic laboratories	Implement incentive programs to encourage their junior technologists to take the ABRET EEG1 examination as soon as they meet the eligibility criteria defined by ABRET

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Appendix A

CAAHEP Accredited Programs

Table A1

Neurodiagnostic Technology Programs – ABRET 2017 listing

Program	City	State
Alvin Community College - Alvin, TX*	Alvin	TX
Bellevue College - Bellevue, WA*	Bellevue	WA
Carnegie Institute	Troy	MI
Catawba Valley Community College - Hickory, NC*	Hickory	NC
Community College of Denver ***	Denver	CO
Concorde Career College-San Bernardino*	San Bernardino	CA
Concorde Career Institute-Grand Prairie - Grand Prairie, TX*	Grand Prairie	TX
Crozer-Chester Medical Center (Keystone) - Upland, PA	Upland	PA
Cuyahoga Community College - Cleveland, OH*	Cleveland	OH
DeVry University - North Brunswick, NJ*,**	N. Brunswick	NJ
Erwin Technical Center	Tampa	FL
GateWay Community College-Phoenix*	Phoenix	AZ
Institute of Health Sciences	Hunt Valley	MD
Kirkwood Community College*	Cedar Rapids	IA
Laboure College	Milton	MA
Lincoln Land Community College*	Springfield	IL
Mayo Clinic College of Medicine - Rochester, MN*	Rochester	MN
Medical Education and Training Campus (METC) - Ft. Sam Houston	Ft. Sam Houston	TX
Minneapolis Community and Technical College*	Minneapolis	MN
Orange Coast College*	Costa Mesa	CA
Pamlico Community College - Grantsboro, NC*	Grantsboro	NC
Scott Community College*	Bettendorf	IA
Southeast Technical Institute - Sioux Falls, SD*	Sioux Falls	SD
University of Michigan	Ann Arbor	MI
Vanderbilt University Medical Center - Nashville, TN	Nashville	TN

* Program offers Associate Degree in Applied Science; ** Program is on probation by CAAHEP; *** Accreditation Voluntarily Withdrawn in 2016

Appendix B

Practice Analysis

ELECTROENCEPHALOGRAPHIC TECHNOLOGY PRACTICE ANALYSIS

This Document represents a delineation of the tasks (T) performed and knowledge (K) applied by electroencephalographic technologists in the practice of their profession in all clinical settings. This practice takes place in the context of their unwavering commitment to patient care and safety and their adherence to the highest principles of ethical behavior.

Domain I – Pre-Study Procedures

T-1 Obtain patient health information and additional information from medical records and patient/caregivers in order to plan recording strategies and avoid adverse effects

The safe and effective performance of this task requires knowledge of:

K-1 Elements of a patient history
K-2 Medical terminology
K-3 Effects of medications on patients and recordings
K-4 Neurological Disorders (e.g., seizures, tumors, vascular disease)
K-5 Psychiatric Disorders
K-6 Toxic/metabolic and infectious diseases
K-7 Head trauma
K-8 Neuroanatomy
K-9 Medical contraindications to activation procedures
K-10 Electrographic correlates to clinical entities
K-12 HIPAA standards
K-43 Neuroimaging and other diagnostic procedures
K-44 Allergies and sensitivities (e.g., latex, tape)

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.

The safe and effective performance of this task requires knowledge of:

K-13 Components of an EEG procedure
K-14 Age-specific criteria
K-15 Techniques for establishing rapport
K-16 Cognitive limitations

Domain II - Performing the EEG Study

T-1 Prepare the patient

A. Measure and mark the patient's head to determine the electrode sites
B. Prepare the sites for electrode placements in order to reduce impedance
C. Securely apply the electrodes

D. Check impedance to ensure electrode integrity

The safe and effective performance of this task requires knowledge of:

K-8 Neuroanatomy
K-14 Age-specific criteria
K-15 Techniques for establishing rapport
K-16 Cognitive limitations
K-17 Electrode placement (i.e., 10-20, T1, T2)
K-18 Metric system
K-19 Infection control
K-20 Conditions affecting impedance
K-21 Electrode application techniques (e.g., paste, collodion, needle electrodes)
K-22 MSDS/OSHA standards
K-23 Characteristics of the differential amplifier (e.g., polarity, CMRR)
K-24 Range of standard impedance values
K-44 Allergies and sensitivities (latex, tape)

T-2 Perform the EEG study according to ACNS Guidelines while ensuring the integrity of the data and equipment

The safe and effective performance of this task requires knowledge of:

K-1 Elements of a patient history
K-2 Medical terminology
K-3 Effects of medications on patients and recordings
K-4 Neurological Disorders (e.g., seizures, tumors, vascular disease)
K-5 Psychiatric Disorders
K-6 Toxic/metabolic and infectious diseases
K-7 Head trauma
K-8 Neuroanatomy
K-9 Medical contraindications to activation procedures
K-10 Electrographic correlates to clinical entities
K-14 Age-specific criteria
K-16 Cognitive limitations
K-20 Conditions affecting impedance
K-23 Characteristics of the differential amplifier (e.g., polarity, CMRR)
K-25 ACNS Guidelines
K-26 Troubleshooting techniques
K-27 Activation procedures
K-28 Artifact monitoring, identification, and elimination
K-29 EEG patterns
K-30 Effects of instrument settings (e.g., filters, display gain, epoch)
K-33 Digital instrumentation concepts (e.g., reformatting, sampling rate, video, calibration, post-acquisition review)
K-40 Waveform analysis (e.g., frequency, duration, voltage)

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

The safe and effective performance of this task requires knowledge of:

K-1 Elements of a patient history
K-2 Medical terminology
K-3 Effects of medications on patients and recordings
K-4 Neurological Disorders (e.g., seizures, tumors, vascular disease)
K-5 Psychiatric Disorders
K-6 Toxic/metabolic and infectious diseases
K-7 Head trauma
K-8 Neuroanatomy
K-9 Medical contraindications to activation procedures
K-10 Electrographic correlates to clinical entities
K-14 Age-specific criteria
K-16 Cognitive limitations
K-17 Electrode placement (i.e., 10-20, T1, T2)
K-20 Conditions affecting impedance
K-23 Characteristics of the differential amplifier (e.g., polarity, CMRR)
K-25 ACNS Guidelines
K-26 Troubleshooting techniques
K-27 Activation procedures
K-28 Artifact monitoring, identification, and elimination
K-29 EEG patterns
K-30 Effects of instrument settings (e.g., filters, display gain, epoch)
K-31 Polarity and localization techniques
K-32 Montage modifications
K-33 Digital instrumentation concepts (e.g., reformatting, sampling rate, video, calibration, post-acquisition review)
K-37 Electrical safety techniques
K-40 Waveform analysis (e.g., frequency, duration, voltage)

T-4 Document patient behavior and clinical events to provide additional information for the interpretation

The safe and effective performance of this task requires knowledge of:

K-34 Significant patient behaviors and clinical events (e.g., changes in level of consciousness, body movements, episodes)

Domain III - Post-Study Procedures

T-1 Remove the electrodes, clean the electrode sites and clean and disinfect electrodes and equipment

The safe and effective performance of this task requires knowledge of:

K-1 Infection control
K-2 MSDS/OSHA standards

T-2 Process acquired data

The safe and effective performance of this task requires knowledge of:

K-3 HIPAA Standards
K-4 Significant patient behaviors and clinical events (e.g., changes in level of consciousness, body movements, episodes)
K-5 Media management (copy, storage, archive, etc.)

<u>T-3</u> Ensure that scheduled maintenance of equipment is performed

The safe and effective performance of this task requires knowledge of:

K-6 ACNS Guidelines

<u>Domain IV - Ethics and Professional Issues</u>

T-1 Conduct practice in a manner consistent with the ABRET Code of Ethics, professional standards and national regulations

The safe and effective performance of this task requires knowledge of:

K-35 The ABRET Code of Ethics

T-2 Ensure patient safety

The safe and effective performance of this task requires knowledge of:

K-19 Infection control
K-22 MSDS/OSHA standards
K-36 National Patient Safety Goals
K-37 Electrical safety techniques
K-39 Seizure precautions
K-44 Allergies and sensitivities (latex, tape)

Appendix C

Examination Development

Exam Development Process

1. A Job Analysis is developed by experts in the field (subject matter experts or SMEs.) This process is facilitated by a psychometrician, reviewed and validated by credentialed technologists. This document becomes the blueprint for the examination.
2. The ABRET Examination Development Committee (EDC) invites credentialed technologists to apply to be item writers. An application and agreements are required. Item writers participate in an online training process, and their initial submissions are critiqued. Each item writer then receives an assignment for writing questions and is given a deadline.
3. The Professional Testing Corporation (PTC) is ABRET's Testing Service Provider. PTC receives the questions developed by the item writers and formats each for review.
4. An Item Review Session is conducted for each credentialing examination at least once a year. The item reviewers are also SMEs from around the country. These sessions are facilitated by a PTC psychometrician. During the review session, each exam item is coded to match the Practice Analysis.
5. The items accepted during the review session are placed into the appropriate Item Bank at the PTC Office in New York.
6. PTC is responsible for selecting the items for each exam, based on the specifications for the exam provided by the SMEs and EDC, and approved by the ABRET Board of Directors.
7. The ABRET Board of Directors, with the appropriate credentials, and at least one physician certified by the American Board of Clinical Neurophysiology review each form of the credentialing examination along with a PTC psychometrician.
8. Each item is reviewed for clarity, relevance, and accuracy and the key verified.
9. The examination is evaluated on how it meets the examination specifications at the time of review.
10. Once the validation process is complete, a cut score study is performed by the exam reviewers. This sets the passing score for the particular form of the examination.

The current practice analysis for each exam is available on the website.
http://abret.org/candidates/credentials/practice-analysis/

IRB

This study was deemed non-human subject research and did not require an IRB approval.

estwani@sbcglobal.net

From:	Griffin, Danielle <dgriffi5@Central.UH.EDU>
Sent:	Monday, February 12, 2018 4:57 PM
To:	Sami Elestwani
Cc:	estwani@sbcglobal.net
Subject:	RE: IRB
Follow Up Flag:	Follow up
Flag Status:	Flagged

Good Morning

If these published reports are anonymous and publically available, then IRB approval is not required.

Danielle Griffin, MS, CIP
Compliance Specialist
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Send Kudos: Recognizing someone for a job well done can do wonders. If a member of the Division of Research staff provided you with good customer service or did an exceptional job, we want to know about it. Kudos will be shared with the recipient and with staff in the division's monthly newsletter. You can send an anonymous Kudos if you wish.

From: Sami Elestwani [mailto:selestwani@sidraorg]
Sent: Sunday, February 11, 2018 3:07 AM
To: dgriffin5@uh.edu
Cc: estwani@sbcglobal.net
Subject: IRB

Greetings Ms. Griffin,

My name is Sami Elestwani, I am a doctoral candidate at the College of Education's Professional Leadership – Health Science Educator program. (http://medical.coe.uh.edu/executive-doctorate.htm)

I have recently defended my thesis proposal. During the proposal defense discussion, Drs. Bernard Robin and Erwin Handoko suggested that since I will be using published reports as my thesis data source, I may not have to go through the IRB application process.

The data I intend to use in my thesis are part of reports published by American Board of Registration of Electroneurodiagnostic Technologists (ABRET).
These reports contain aggregate examination results for each board examination instance (three instances each year). They do not include any individual data on the candidates, only aggregate examination statistics are included in these reports.

Dr. Bernard Robin, suggested I contact you to clarify whether an IRB is needed in this case, especially that the data source are the published reports.

Looking forward to hearing from you.