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Understanding the Cranial Nerves: Evaluation of a Self-Paced Online Module in Optometric Education

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UNDERSTANDING THE CRANIAL NERVES: EVALUATION OF A SELF-PACED ONLINE MODULE IN OPTOMETRIC EDUCATION

by

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Acknowledgements

It is strange that, having produced the tens of thousands of words contained in this document, I only experienced writer's block when I set my hand to this section. This is not the effect of ingratitude, I don't think, but its opposite: every time I begin enumerating my various influences, their magnitude and diversity confuses me. Therefore, I apologize for the insufficient (but sincere!) acknowledgements that follow.

As an alumnus, I have long contended that the undergraduate scientific training I received at the University of Memphis is comparable in quality to most any other program in the country. I am pleased to report the same is true for the doctoral education program. The Instructional Design and Technology faculty—particularly Drs. "Trey" Martindale, Carmen Weaver, Clif Mims, Suha Tamim, and Michael Grant—created an effective, exciting learning environment that forced me to evaluate both why I teach and how, and provided material support for the ideas I have explored in this dissertation.

It is not an overstatement that Dr. Martindale's 2011 consultation at Southern College of Optometry changed the direction of my career. His thoughtful, literature-based insights into our curriculum piqued my curiosity in the formal study of education. Later, as my academic advisor and dissertation committee chair, Dr. Martindale's light touch communicated deference to my initiative while simultaneously emphasizing the program's inexorable requirements. This balancing act is crucial to the success of this document.

When I first expressed interest in pursuing a doctorate in education, the Southern College of Optometry administration, specifically Drs. Lewis Reich, J. Bart Campbell, and Patricia Estes-Walker, expressed nothing but encouragement and support. When this mere germ of an idea grew into a concrete reality with tangible tuition statements, they paid them all. When my class requirements conflicted with my clinical assignments, they accommodated. I am grateful beyond words.

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In 1986, my father and mother, Jimmie and Sharon Taylor, frustrated with the quality of local public education and the cost of local private education, took a then-uncommon step to teach me and my brothers themselves. I don't think they intended to be trendsetters, though they did climb on the modern homeschooling bandwagon just as it was getting started. Their wisdom is obvious in the successes of their sons: academic success, of course, but also vocational, moral, and familial success. In short, they supplied us with more than mere skills and knowledge, but a philosophy of learning: an amalgam of my father's rational criticism, my mother's joyful intellect, and a firm belief in biblical first principles. My father has gone on to his reward; my mother remains to serve.

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Finally, the unexpected variable, Miss Hannah Bliss Taylor, one-year-old at this writing, and (logistically-speaking) more a distractor from this dissertation than a contributor; she has nevertheless given my life colors and depths I never knew before. She motivated me to work harder and finish faster, so I would not miss her childhood for the sake of a degree. In this most loving and gentle way, she held my feet to the fire. Hannah, I love you as you are; I cannot wait to know the person you will become.

Abstract

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Among the faculty of Southern College of Optometry in Memphis, Tennessee, it is perceived that optometry students often enter their clinical assignments with poor clinical judgment. To address this, *Understanding the Cranial Nerves*—an online-self paced instructional intervention of approximately two hours' duration—was developed. In it, the content is presented in a clinical context, in order to foster development of clinical thinking and factual recall.

The purpose of this study is to determine the effect of this intervention upon first-year optometry students' clinical thinking and content knowledge. Improvements in these subjects were measured using identical pre-/post-tests, and analyzed with Student's *t*-tests ($n = 66$). Both factual recall [t (65) = 15.984, $p < .001$] and clinical thinking [t (65) = 16.115, $p < .001$] improved significantly.

The study's secondary purpose is to understand students' perceptions of the intervention. These were measured immediately after completion with an attitude survey, which was designed to measure perceptions of the content, aesthetics, and usability. For the 19 Likert-type items on this instrument, the frequency distributions of the responses were compared to an expected distribution using Pearson's *chi*-squared goodness-of-fit tests ($n = 61$). Significant responses included higher distributions on three course content items [χ^2 (4) = 14.705, $p = .005$; χ^2 (4) = 22.641, $p < .001$; χ^2 (4) = 23.308, $p < .001$], and lower distributions on five usability items [χ^2 (4) = 39.975, $p < .001$; χ^2 (4) = 42.476, $p < .001$; χ^2 (4) = 60.476, $p < .001$; χ^2 (4) = 41.619, $p < .001$; χ^2 (4) = 35.105, *p*

$< .001$]. A cursory analysis of the remaining two free-response items showed general satisfaction with the intervention content but frustration with its usability ($n = 25$). Semi-structured interviews given several months after completion of the intervention yielded similar results ($n = 8$). Altogether, the study suggests that self-paced, online content like *Understanding the Cranial Nerves* can be useful for improving factual recall and clinical thinking in optometric education. The lack of a control group and short duration of the study call its generalizability into question. Usability concerns must be addressed if the intervention is to be implemented.

Table of Contents

List of Tables

Chapter 1: Introduction

Over the past several decades, educational researchers have expended considerable effort studying the phenomenon of *critical thinking*, both to define it and determine how to engender its development in students (Dunne, 2015). Educators in the *health professions* (e.g., dentistry, nursing) are similarly interested in critical thinking, as it is a foundational component of *clinical thinking*, a cognitive process that effective clinical practice is based upon (Faucher, 2011). This wide-spread interest in critical thinking research happened to rise simultaneously with the development of the Internet and online learning, coincidentally and perhaps serendipitously raising the academic question of how online instruction may be used to develop critical thinking ability (Chit Ming, 2014; Clegg et al., 2014; Cook & Triola, 2009; Forneris & Peden-McAlpine, 2007; Santiago, 2011; Wilgis & McConnell, 2008; Wyles, McLeod, & Goodfellow, 2013).

In order to think critically, one must first possess knowledge to think critically *about*. Thus, in optometric education (as in the other health professions), students begin their studies by mastering a two-year basic science curriculum, which supports the more sophisticated lessons of clinical experience. This basic science curriculum is intensive, with course loads of more than 20 credit hours per semester, and includes courses in optics, the theory and practice of optometric clinical skills, vision science, biochemistry, gross and ocular anatomy and physiology, pharmacology, and neuroanatomy (Southern College of Optometry; 2015b).

It is an important goal in optometric education to develop critical thinking among future optometrists. For example, at Southern College of Optometry (SCO) in Memphis, Tennessee, critical thinking and its corollaries—lifelong learning and clinical thinking—

are identified by the administration and faculty as points of emphasis for its curriculum (SCO, 2009, 2013). Yet, the extensive semester load described above makes it challenging for the SCO faculty to find time for critical thinking instruction during the first two years of the program. To combat this, basic science course instructors attempt to integrate higher-order thinking into their lessons by weaving clinical discussions into their content, and developing examination items that require higher-order cognition. For example, the current *Neuroanatomy* course at SCO is primarily lecture- and reading-based, though scattered within this foundation are a variety of clinically applicable, open-ended case vignettes designed to improve students' critical thinking. The problem is that such elements are often isolated experiences within a curriculum that does not necessarily support the development of long-term critical thinking ability (Taylor, 2015; Tiruneh, Verburgh, & Elen, 2014). The large class sizes (i.e., over 130 students in each course) also make both genuine classroom discussion and thoughtful evaluation difficult to implement and maintain.

SCO, like many other institutions of higher learning, uses an in-house *learning management system* (LMS) accessible to all faculty and students. The SCO LMS is a version of the open-source *Moodle* platform, with the capability to host files, administer quizzes, report grades, host asynchronous and synchronous discussions, and present interactive lessons, along with other functions. With *Moodle*, instructors can expand their courses to make them more interactive, more self-paced, and less dependent on defined classroom time.

Statement of the Problem

In spite of all of this knowledge and innovation, there is a perception among the faculty at SCO that students' mastery of the basic science knowledge foundation often erodes significantly after their successful completion of foundational courses. Thus, students often enter the first clinical assignments of their third academic years ignorant of some important fundamentals. Worse is the perception that these students have difficulty not only recalling material, but also expressing or applying what they know in a useful manner (Taylor, 2015). This difficulty could prevent students from drawing appropriate and important conclusions from their inevitable clinical mistakes, partially negating the full benefit of clinical experience.

Since critical thinking (based on knowledge mastery) is vital to clinical practice in optometry, it is important that optometry students master the foundational material while simultaneously practicing and developing their critical thinking skills and dispositions, both within and apart from clinical practice. Though limited, existing findings suggest that well-designed, interactive, problem-based content may facilitate simultaneous knowledge acquisition and critical thinking development (Carey, Kleiman, Russell, Venable, & Louie, 2008; Cho & Herron, 2015; Russell, Kleiman, Carey, & Douglass; 2009).

Accordingly, the researcher developed *Understanding the Cranial Nerves*, an online, self-paced, clinically-based instructional intervention, to address these concerns. Its outcomes will be evaluated in this study.

Purpose of the Study

The purpose of this study is to determine the efficacy of a self-paced, online, clinically-based instructional intervention upon first-year optometry students' immediate knowledge of clinically-based cranial nerve structure and function. Since both factual recall and clinical decision making are vital to optometry students' education, both will be considered. A secondary purpose of the study is to understand students' perceptions of this intervention in the contexts of their classroom and clinical education.

Significance of the Study

This study seeks to determine whether a carefully designed, self-paced online learning module can improve student comprehension of cranial nerves in clinical and critical thinking contexts, and to evaluate how students perceive such an intervention. It will contribute to the literature as a case report, strengthening the argument for or against such interventions.

Since many optometry professors have no formal andragogical training, it is common for these educators to simply teach as they had been taught. If it can be demonstrated that *Understanding the Cranial Nerves* is practically useful in imparting desired knowledge and clinical thinking ability, it could serve as an example for the development of online, clinical thinking-based material in other optometric courses. Educators in other health care professions may be similarly interested in the findings, as might college professors engaged in the difficult task of teaching clinical *cranial nerve assessment*.

The findings may help substantiate the theoretical underpinnings of constructivist self-paced online education. As described elsewhere in this document (see Chapter 2, Self-Paced Learning, below), Anderson's (2003) *equivalency theorem* states that formal learning occurs as the result of interactions between learners, the instructor, and the material. The results of this case report will provide one more iota of evidence to either support or cast doubt upon the utility of constructivist theory in online, self-paced course design (Carey et al., 2008; Rae & Samuels, 2011; Russell et al., 2009; Svenningsen & Pear, 2011).

Definition of Terms

Throughout this document, the following terms will be used often or in crucial contexts. Though some terms are defined here for ease of reading, others—like *clinical judgment*, clinical thinking, and critical thinking—are subtly but importantly distinct, and are therefore commended especially to the reader's attention. Broad philosophies of learning (such as behaviorism and constructivism) are not defined here, as they are well-described throughout the literature.

Clinical judgment. Clinical judgment is the process of "deliberate or conscious decision-making, with a particular emphasis on higher-level awareness, discrimination and evaluation in the face of complexity of professional practice" (Faucher, 2011, p. 142). It is the first step in clinical reasoning, and exploits previously-learned knowledge, available resources, and critical thinking ability, all of which guide the clinician to several possible diagnoses. It is clinical judgment that allows the clinician to weigh the pros and cons of each possible diagnosis and to decide upon the best option.

Clinical thinking. Clinical thinking is the overarching thought process of the physician, and includes clinical inquiry, reasoning, and judgment. Extant knowledge, external resources, critical thinking skills, and clinical reasoning all are elements of the overarching clinical thinking process. Its ideal output is a plan of action that maximizes each particular patient's wellbeing (Faucher, 2011).

Computer-assisted Personalized System of Instruction (CAPSI). CAPSI is a proprietary online software program specifically designed to aid in administration of a

Personalized System of Instruction (PSI) course. Due to the nature of PSI courses, they often require onerous administrative work (see PSI, below). The unique design of CAPSI automates much of this, making it easier to develop and implement such a course (Pear & Crone-Todd, 1999).

Cranial nerve assessment. Cranial nerve assessment is the step-by-step evaluation of each of the 12 cranial nerves in clinical practice using a series of prescribed tests. The normal optometric examination evaluates five of the cranial nerves. Should the general neurological evaluation, patient's complaint, or results of the examination imply the likelihood of neurological involvement, a cranial nerve assessment can identify the presence of a dysfunction, the neurological region affected, the likely severity, and opportunity for treatment (Barker & Moore, 1992).

Critical thinking. An element of clinical thinking, critical thinking can be defined as the analysis of one's own thought processes to improve those processes. In practice, the careful clinician uses critical thinking to consistently evaluate his or her thinking for unsubstantiated assumptions, biases, and shortcuts that could lead to a misdiagnosis (Faucher, 2011).

Equivalency theorem. The equivalency theorem as discovered and stated by Anderson (2003) is as follows:

> Deep and meaningful formal learning is supported as long as one of the three forms of interaction (student-teacher; student-student; student-content) is at a high level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience. High levels of more than one of these three modes will likely provide a more satisfying educational experience, though these

experiences may not be as cost or time effective as less interactive learning sequences. (Equivalency of Interaction section, para. 2)

Learning management system (LMS). A LMS is an online software program that “provides the structure for the delivery and management of the learning process of [an] institution as a whole” (Babo & Azevedo, 2012, p. 9). A LMS makes it relatively simple to create and publish the common components of an online course.

Multimodiality theory. The *multimodiality theory* contends that communication occurs in all aspects of a person’s social context, including verbal, written, kinesthetic, and spatial forms. Since instruction has traditionally focused upon the first two of these forms, proponents of the multimodiality theory in education tend to focus on the study of kinesthetic and spatial forms of educational communication (Jewitt, 2012).

Neurological assessment. Though it can be extensive or brief, the purpose of a clinical *neurological assessment* is the same: to classify a patient’s neurological status in order to identify the risk of disorders (Snyder, Nussbaum, & Robins, 2006). The clinical optometrist’s neurological assessment is a screening tool that alerts the clinician to possible dysfunction, so that the clinician may conduct additional testing or refer the patient to an appropriate specialist.

Personalized System of Instruction (PSI). PSI is a method of course design and administration based heavily on behaviorist teaching philosophy. PSI methodology purports greater learning for students than traditional methods by enacting five main principles: (1) requisite mastery of material, (2) use of student proctors, (3) self-pacing of material, (4) content presentation via the written word, and (5) lectures as a reward (Kulik, Kulik, & Cohen, 1979). The development of the personal computer and Internet has breathed new life into PSI (see CAPSI, above).

Self-regulation. *Self regulation* is the “individual’s capacity to plan, control, evaluate, and adapt thoughts, feelings, and behaviors to achieve personal goals” (Dubuc-Charbonneau & Durand-Bush, 2015, p. 175).

Self-regulated learning (SRL). “*SRL* refers to students’ systematic effort to manage their learning process to achieve goals” (Cho & Heron, 2015, p. 81). This effort is thought to take three forms: (1) the learner’s motivation to learn, (2) the learner’s emotions (whether positive or negative) and ability to promote emotions conducive to learning, and (3) the learner’s use of cognitive learning strategies to deeply understand challenging material.

Virtual patients. A *virtual patient* is computer software programmed to simulate a clinical examination. The virtual patient’s complaints, clinical signs and symptoms, and reactions to examination are based upon what real patients might do in a clinical setting. Students interact with the software in ways that mimic real testing, and arrive at diagnoses using the same clinical thinking process (Johnson et al., 2013; Johnson et al., 2014).

Virtual worlds. *Virtual worlds* are “synchronous, persistent network[s] of people, represented as avatars, facilitated by networked computers” (Bell, 2008, p. 2).

Research Questions

Based upon the material presented above, the important variables for evaluation of *Understanding the Cranial Nerves* are factual recall and clinical thinking. By studying these, the intervention’s practical efficacy can be determined, relative to the previously-described perceived needs of SCO faculty. The literature is unclear as to whether online, self-paced instruction results in improved clinical educational outcomes compared to traditional forms of content presentation (Chit Ming, 2014; Chu & Borstag, 2009; Clegg et al., 2014; Cook & Triola, 2009; Forneris & Peden-McAlpine, 2007; Goodwin, Hua, & Hayes, 2014; Johnson et al., 2013; Johnson et al., 2014; Peterson-Klein, Vance, & Swan, 2004; Resuehr, Lowman, Waugh, & Edison, 2014; Santiago, 2011; Seif, Brown, & Annan-Coultas, 2013; Southard, Meddaugh, & France-Harris, 2015; Svenningsen & Pear, 2011; Taylor, Luplow, & Buckingham, 2015; Whiteside, Ge, Fong, & DiMartino, 2015; Wilgis & McConnell, 2008; Wyles et al., 2013; Yeung, Fung, & Wilson, 2012). Thus, it is useful to determine to what extent factual recall and clinical thinking variables change as a result of the intervention.

To maximize the effective design of the intervention, student perceptions were also measured and analyzed for insights. These perceptual data (along with the implications of the educational outcomes data) will help determine whether *Understanding the Cranial Nerves* should be implemented permanently in the SCO basic science curriculum.

Based on these considerations, four research questions were developed:

1. To what extent does completion of a self-paced, online cranial nerve intervention improve factual recall among first-year optometry students?
2. To what extent does completion of a self-paced, online cranial nerve intervention improve clinical thinking ability among first-year optometry students?
3. What are the perceptions of first-year optometry students about a self-paced, online cranial nerve intervention immediately after completing it?

4. What are the perceptions of first-year optometry students about a self-paced, online cranial nerve intervention after finishing the course that contained the intervention?

Hypotheses

The following null hypotheses will evaluate the first three research questions. Respectively, they are:

1. Factual recall of cranial nerve content is not improved by the completion of a self-paced, online cranial nerve intervention among first-year optometry students.
2. Clinical decision making regarding cranial nerve assessment is not improved by the completion of a self-paced, online cranial nerve intervention among first-year optometry students.
3. The frequency of responses to any individual Likert-type item matches the following expected frequencies: Choice 1: 1.64%; Choice 2: 4.92%; Choice 3: 8.20%; Choice 4: 11.48%; Choice 5: 73.77%

Being perceptual in nature, the fourth research question and the survey component of the third do not have related null hypotheses.

Limitations

The study has the following limitations:

1. The proposed instructional intervention is limited by its inclusion within the first-year course work at SCO, which makes random grouping of participants into control and treatment groups ethically untenable. The quantitative treatment groups are thus composed of convenience samples based upon

enrollment and voluntary participation in the study, which decreases the internal validity of the study and its potential for generalization (Behar-Horenstein & Niu, 2011).

2. *Understanding the Cranial Nerves* was implemented as part of the SCO first-year *Neuroanatomy* course, for which the lead investigator of this study is the instructor of record. Since cranial nerves are only one component of the course, the intervention's duration is limited to approximately one- to two-hours of online instruction. However, as described in Niu, Behar-Horenstein, and Garvan (2013), critical thinking ability develops most effectively and permanently with curriculum-wide adoption of appropriate instructional techniques. Though the SCO administration is amenable to curricular updates, a previous attempt to implement curriculum-wide problem-based learning by administrative fiat led to substantial faculty and student resistance. Consequently, instructional changes at SCO tend to arise from either small, incremental curricular updates or the serendipitous instructional decisions of individual course instructors, effectively limiting the duration of any curricular change to a semester's length. These factors objectively restrict the clinical thinking training in *Understanding the Cranial Nerves* to a less-than-ideal duration. An expanded implementation over time would increase the likelihood of a significant research effect. Even in the pretense of a significant effect, the short duration of the intervention could lead to reduced credibility if the effect size is small (Niu et al., 2013).

Delimitations

The proposed study is delimited in several ways:

1. Though there are a variety of commercially available instruments for assessing critical thinking skills and dispositions, one of the emphases in this study is optometric clinical thinking, for which standardized instruments are not available and critical thinking is only a component element. Therefore, a standardized score was not used to evaluate these higher-order processes. Rather, the researcher used assessment items that require clinical thinking to determine the correct answer. These were developed by the researcher, according to his expertise as instructor of the *Neuroanatomy* course at SCO. This opens the results to criticism that the selected evaluation items may not effectively test clinical thinking, potentially reducing the study's validity.
2. Though it would have been interesting to measure participants' long-term factual recall and clinical thinking as a result of the intervention content, such an element was rejected out of deference to the extensive workload of the first-year students. In spite of the consequential reduction in internal validity and generalizability that could result, the researcher deemed it an unfair burden to add another factual recall assessment to students' already full schedule, months after the intervention was completed (Behar-Horenstein & Niu, 2011).

Assumptions

It is assumed in this study that the first-year student population at SCO was similar to that of other schools and colleges of the health professions in the United States of America, and that instructor-identified clinical thinking assessment items were accurate, valid, and reliable measurements of clinical thinking.

Organization of the Study

This proposal contains five chapters. Chapter 1 has introduced the research problem that was studied, describing its background, significance, research questions and hypotheses, limitations, delimitations, and assumptions. Chapter 2 will extensively review the pertinent literature to support the important elements of this study; namely, multimodiality theory, self-paced learning, online education in optometry, and critical and clinical thinking. Chapter 3 is a description of the research methodology, including how participants were selected, the instruments that were used, and how data were collected and analyzed. Chapter 4 presents the results of this methodology as it relates to the four research questions. Finally, Chapter 5 investigates the meaning of the findings, the implications for educational practice, and future research emphases that could elaborate upon this study and its themes.

Chapter 2: Review of the Literature

The curricula in American schools and colleges of optometry are designed to educate college graduates in the elements of the optometric discipline, which include foundational knowledge, clinical skill, clinical judgment. The optometrist, though a physician, is not trained as a medical doctor and, as such, is limited in practice to diagnosing and treating refractive error, functional disorders of the visual system, and diseases of the eye and surround. Systemic diseases are not treated by optometrists, but may be identified during the course of a routine optometric examination. A timely referral in such a situation could potentially prevent mortality or morbidity. Thus, optometry students must understand the gross anatomy, histology, and neurophysiology of the twelve cranial nerves to appropriately assess their patients' health. In the course of a normal eye examination, a patient's gross neurological state and the functions of several of the cranial nerves are tested either directly or indirectly. These elements of the examination sequence are referred to as neurological assessment and cranial nerve assessment, respectively. Optometrists should be able to identify the clinical presentation of general and discrete neurological conditions and perform the appropriate tests in office for accurate diagnosis. Thus, an effective andragogy of cranial nerve knowledge, assessment, and treatment is an essential element of optometric education (Moore & Chalk, 2009).

As described by Taylor (2015, September 13), students at SCO often find cranial nerve concepts difficult to learn and retain. This is evidenced by the finding that examination results in the first-year *Neuroanatomy* course were inversely proportional to the percentage of cranial nerve questions on each. This manifest difficulty in mastering cranial nerve concepts is concerning due to the clinical relevance of the material. A well-designed instructional intervention could theoretically mitigate this problem.

In educational literature, effective teaching techniques in medical, health professions, and optometric settings are widely discussed; however, the volume of sometimes-contradictory information can make the ideal model of instruction for a particular scenario difficult to identify. The purpose of this literature review is to examine the available body of knowledge for theories, trends, contradictions, errors, and evidence related to the development of online, self-paced interventions. Emphasis will be placed on the role of critical thinking in such interventions, and methods for the accessible teaching of cranial nerve concepts. The discussion is organized around four subjects that correspond to the detailed elements of the intervention: (1) the theory of multimodiality, (2) self-paced education, (3) online education in optometry, and (4) critical thinking and clinical thinking.

When gathering sources for this literature review, multiple databases were used to assure comprehensive scope. The most commonly used databases were *Google Scholar* (linked to the University of Memphis' catalog) and the *Encore* catalog tool, which queries multiple databases simultaneously, including the University of Memphis library holdings. When more extensive or specific findings were needed, *Education Full-Text*, *EBSCO*, *PsycInfo*, *ERIC ProQuest*, *Social Sciences Citation Index*, and *SCOPUS* databases were consulted. Using applicable keywords, the researcher queried these databases through the University Libraries system at the University of Memphis. The number of used keywords expanded as articles were reviewed and new concepts and terms were identified. This used keyword list is reproduced in Appendix A.

Articles from the *Journal of Optometric Education* are not cataloged in the Encore tool. Since this is the primary journal for educational technique and theory in optometry, the researcher manually reviewed its online archives (located at http://journal.opted.org) for pertinent articles.

As the literature search progressed, it was occasionally useful to browse the lists of sources that either cited, or were cited within obtained articles. *Google Scholar* was particularly well suited to run this search strategy, which yielded many useful results.

Multimodiality Theory

Though there is a dearth of information about the specific instruction of cranial nerves in the optometric educational literature, the subject is explored in more detail in undergraduate, health professions, and medical contexts. The included interventions are generally founded upon a multimodal educational philosophy, popular in current anatomical andragogical practice. According to the multimodiality theory, communication occurs throughout all aspects of a person's social context, from the more traditionally-studied verbal and written forms to kinesthetic and spatial forms. According to Jewitt (2012), "multimodiality emphasizes the importance of the social context and the resources available to people to make meaning…" (p. 3). Consideration of multimodal forms of communication can provide new perspectives on educational issues and help equalize power between all participants (pp. 6-8).

Since multimodiality theory holds that previously underemphasized forms of communication are of equal importance to the traditional, it follows that studies of this concept in educational settings will yield considerable research regarding the creation, implementation, and effectiveness of innovative teaching methods. It is no accident that the recent interest in multimodal educational techniques has concurred with the development of digital and online educational resources, which ease the implementation of multimodal instructional presentations (Jewitt, 2012, pp. 11-13).

Multimodiality in gross anatomical andragogy. Gross anatomical education is no exception to the multimodal trend. In their brief summary of the pertinent medical educational literature, Drake and Pawlina (2013) review how multimodal education has been used to enhance gross anatomical classroom techniques and outcomes, and how the theory may continue to be practically manifested in future contexts. Vital emphases in effective multimodal instruction include (1) active learning techniques, (2) efficient kinesthetic experiences in both laboratory and clinical contexts, (3) exposure to clinically-based imaging of structures, and (4) long-term reinforcement. Specific examples illustrate the importance of these emphases. Böckers, Mayer, and Böckers (2013) presented the clinical context of their gross anatomical material by adding hands-on operating room experiences and in-person demonstrations of surgical technique to their nursing curriculum. Though non-technical, their innovations led to a rise in learning motivation and orientation. Several computer- and Internet-based innovations have been described as well, demonstrating both the addition of discrete digital elements to existing lecture-based courses (Green, Farchione, Hughes, & Chan, 2013; Stirling & Birt, 2013) and a comprehensive course redesign around a core of online material (Rizzolo et al., 2010).

Multimodiality in cranial nerve andragogy. In neuroanatomical education—specifically when teaching the cranial nerves and their assessment in the health professions—the multimodiality theory has been applied generously. Many and various mechanisms have been described to aid in teaching the cranial nerves. Non-digital examples include the construction of rude representations of affected organs (Zhang & He, 2010) and the use kinesthetic miming to aid memory of pertinent facts (Dickson & Stephens, 2015). These hands-on techniques have been shown to improve factual recall and course outcomes. The majority of recent interventions, however, are digitally based, as they were developed and hosted using computer- and Internet-based technology.

Internet videos. Latha, Prakask and Lobo (2011) placed computer-based text and videos of cranial nerve assessment techniques on a LMS, to be used as supplementary aides among undergraduate nursing courses. However, they failed to identify any appreciable positive effect on knowledge or skills compared to a control group. Addressing the possibility that lack of improvement from such video content may be due to poor quality, Azer, AlEshaiwi, AlGrain, and AlKhelaif (2012) developed a method for determining the educational value of online cranial nerve assessment videos. They queried the video sharing website *YouTube* with pertinent keywords, and evaluated the results according to their fulfillment of previously identified outcomes-based criteria. The authors were able to separate educationally-useful videos from the non-useful using this rating scheme.

Computer atlases. Several researchers have built computer-based atlases to act as three-dimensional, interactive resources for the study of cranial nerve anatomy, function, and disease. These include drawings of the cranial nerves, their supporting structures, and surroundings—once the exclusive province of textbooks—in an interactive format for easy manipulation by learners. While most of these have been developed using in-house proprietary technologies (Nowinski & Chua, 2013; Nowinski, Johnson, Chua, &

Nowinski, 2012; Nowinski et al., 2015), one example describes a unique application of the virtual world concept. A virtual world, as defined by Bell (2008), is "a synchronous, persistent network of people, represented as avatars, facilitated by networked computers" (p. 2). Though a more complete exploration of virtual worlds in education is beyond the scope of this review, its possibilities for team learning and interactivity are obvious. Using the freely accessible Internet-based virtual world *Second Life*, Richardson-Hatcher, Hazzard, and Ramirez (2014) created a "cranial nerve skywalk" that students could vicariously explore through the perambulations of their own personalized avatar. Regardless of the particular interface, the concern with these computer-based cranial nerve atlases is similar: there is an absence of data to support their andragogical efficacy. The cited examples merely describe the specific features of each resource, and fail to investigate whether their innovations translate to improved outcomes and understanding.

One exception to this is the work of Yeung et al. (2012), who used three-dimensional interactive video atlas resources as a LMS supplement to an existing undergraduate anatomy course. These video resources specifically covered one particular cranial nerve, the trigeminal nerve. Both treatment and control group members completed a team-based module covering the content without computer assistance, while treatment members also completed the LMS-based content individually. Members of both groups answered questions on trigeminal spatial relationships along with several qualitative questions about the course. Though the authors found no significant improvement in knowledge transfer between treatment and control, qualitatively their participants rated the computer-assisted curriculum as easier to use and better organized than its team-based counterpart. However, both treatment and control groups preferred lectures to computer atlas presentations.

Simulations. Recently, the development and use of patient simulation in health professions' training has been a subject of some study. Both robotic simulators and computer-programmed virtual patients have been developed to allow instructors to engage students in a clinically faithful environment, even regarding the cranial nerves (Willis & Van Sickle, 2015). Wang et al. (2012) and Wang et al. (2014) created robotic simulations for assessment of the five cranial nerves most related to the eye. However, the authors do not evaluate their creations for educational efficacy.

Johnson et al. (2013) and Johnson et al. (2014) developed computer software-based virtual patients, which are artificial representations of patients with cranial nerve disorders that present and are examined via the computer interface. Learners use the tools of the program to examine the virtual patients, much as they would a real patient, and arrive at a diagnosis and treatment plan for a particular clinical presentation. Though the focus of the studies was on comparing pre-test and post-test changes between team-based and individual learner course organizations, the raw data show that the vast majority of students who completed the virtual patient exercises improved their understanding of the appropriate diagnosis and treatment of cranial nerve disorders. Interestingly, among the students who had the worst pre-test results, team-based participation yielded higher post-test scores than individual participation. This effect was not found among students with better pre-test results.

Implications of multimodiality. Upon review of the preceding sources, it is interesting to note that, of the innovative cranial nerve instructional resources described, only Johnson et al. (2013) and Johnson et al.'s (2012) virtual patient programs demonstrated a positive effect on learning outcomes. Since the purpose of educational innovation in this particular context is to improve such outcomes (with an assumed subsequent improvement in clinical performance), the prudent instructor will evaluate technical innovations critically before undertaking wide implementation.

Self-Paced Education

Of the innovations described above, computer-based examples can be (and often are designed to be) used in a self-paced manner. The virtual patients of Johnson et al. (2013) and Johnson et al. (2012), the computer-assisted LMS supplements of Latha et al. (2011) and Yeung et al. (2012), and the computer atlases of Nowinski and Chua (2013), Nowinski et al. (2012), Nowinski et al. (2015), and Richardson-Hatcher et al. (2014) were all developed to be consumed at the learner's (or team of learners') pace, based upon his or her understanding and feeling of mastery with the material. Therefore, this section reviews the literature behind self-paced educational technique.

Personalized System of Instruction. In 1968, during the height of radical behaviorism's popularity in pedagogical research, a new method of instructional design emerged. Proposed by psychologist Fred S. Keller (1968), the method emphasizes five foundational elements: (1) written materials for content presentation, (2) reservation of lectures for motivational and reward purposes, (3) individualized pacing of material, (4) learning for mastery (usually measured with quizzes given at the end of each content module), and (5) proctoring by advanced students. Keller's method came to be known as the Personalized System of Instruction (PSI) or, eponymously after its primary developer, as the Keller Plan (Driscoll, 2005).

PSI theory holds that traditional education is based upon punishment as a motivator, which is not conducive to effective learning. However, reactionary attempts to remove all compulsory and punitive motivations from education caused a vacuum of rules and guidelines, and students, thusly cast adrift, did not enjoy improved educational outcomes. To combat this, PSI replaces punishment-as-motivator with Skinnerian operant conditioning. Specifically, the self-paced nature of small curricular units harnesses the positive feeling of progression toward a goal (i.e., completion of the course) as reinforcement. With each completed unit, students draw nearer to the goal and feel pride in the material they have mastered. Proctoring by advanced students increases the personal-social interaction of the classroom space and provides reinforcing, pleasant learning experiences as well as immediate feedback on completed work (Keller, 1968; Sherman, 1974).

Impact of PSI. The initial publication of the Keller plan was met with enthusiastic acceptance in the education community, particularly in the social sciences. At the height of PSI's acceptance in the early 1980s, hundreds of articles were published on the technique every year, commonly reporting improved outcomes with PSI compared to traditional lectures (Greenspoon, 1974; Eyre, 2007; Kulik et al., 1979; Sherman, 1992; Taveggia, 1976). By the turn of the 21st century, however, PSI had lost much of its following. Few teachers were performing research on PSI and the number of courses organized according to its principles had dramatically decreased. The reasons for this dramatic change are myriad, but likely include resistance from administration and teachers to the increased workload that comes from using PSI, discord among PSI proponents on the practical implications of the theory, simple inertia against making major changes, and a general trend away from behaviorism as an educational philosophy, in favor of cognitivism and constructivism (Eyre, 2007; Sherman, 1992; Thompson, 2014).

Computer-assisted PSI. In the wake of what was practically a 20-year hiatus, PSI research has begun to reappear sporadically, but increasingly, in the literature. The proliferation of the personal computer and the Internet (and the subsequent revolution of instructional design that resulted from it) has apparently reignited a mild interest in PSI (Eyre, 2007). As early as 1992, Sherman noted that computer-based instruction could theoretically be used as an avenue for the presentation of PSI courses. Pear and Crone-Todd (1999) proved the concept by developing and implementing the *computer-assisted personalized system of instruction* (CAPSI), which runs via the Internet. A proprietary system, CAPSI automates many of the tasks endemic to the PSI model, which mitigates its onerous administrative load. Svenningsen and Pear (2011) showed the potential for such a system by demonstrating improved critical thinking skills in undergraduate students who completed a CAPSI-based course, a point that will be of interest later in the literature review (see Critical Thinking, below).

Brinkman, Rae, and Dwivedi (2007) described the implementation of a PSI course using a commercially available LMS. Unlike CAPSI, which is proprietary and specifically designed for PSI functions, LMSs are software packages that allow for many different course management tasks. The authors found that students reported their LMS-based PSI course was more convenient to use than traditional course presentations. A subsequent study by Rae and Samuels (2011) indicated that a LMS-based PSI course design with embedded video content and formative questionnaires to assess mastery was effective for teaching cognitive skills, particularly to groups of students of diverse educational ability.

Non-PSI self-paced online instruction. Not all self-paced online courses are developed according to PSI strictures. There are many recent examples of self-paced online components being added to existing courses without consideration of PSI, but rather to power the flipped classroom. The flipped classroom is a constructivist course organizational method in which students are exposed to material outside of class first, with classroom time dedicated to interactive activities to deepen understanding. The concept is well described in the literature, has been extensively commented upon recently, and, excepting this paragraph, will not be explored further here. However, it is important to note that flipped classroom material is often presented online with relative self-pacing (Betihavas, Bridgeman, Kornhaber, & Cross, 2015; McLaughlin et al., 2014).

There is some research available on this kind of self-paced online instruction. Carey et al. (2008), and Russell et al. (2009) examined the performance of adult learners in a well-designed self-paced online mathematics education course. Different treatment groups received differing levels of instructor support, from actively involved to limited availability. Interestingly, all groups showed similar improvements in educational outcomes no matter what level of instructor support was provided, and improvements were similar whether students completed the self-paced course individually or in a cohort of three students.

Equivalency theorem. Anderson's (2003) equivalency theorem provides a potential explanation for these observations. The theorem states:

> Deep and meaningful formal learning is supported as long as one of the three forms of interaction (student-teacher; student-student; student-content) is at a high

> level. The other two may be offered at minimal levels, or even eliminated, without degrading the educational experience. High levels of more than one of these three modes will likely provide a more satisfying educational experience, though these experiences may not be as cost or time effective as less interactive learning sequences. (Equivalency of Interaction section, para. 2)

Rhode (2009) tested the equivalency theorem and found that in self-paced online courses, learner interactions with the instructor and the course content are valued at equally high levels, while learner-to-learner interactions are valued less highly. This explains the findings in Carey et al. (2008) and Russell et al. (2009), who varied either learner-to-instructor or learner-to-learner interactions while keeping learner-to-content interactions stable. In spite of these adjustments, educational outcomes did not change, which illustrates the importance of robust interaction between learners and the instructional content.

By analyzing the existing literature, Southard et al. (2015) attempted to describe best practices for developing constructivist self-paced online courses. They methodically designed such a course around four essential elements: (1) consistent structure, (2) high-impact production, (3) rich and dynamic instructional content, and (4) interactive content. However, their undergraduate American government students showed no statistically-significant improvement in examination grades compared to traditional courses.

Self-regulation in online self-paced education. It is worth considering the relationship between success in self-paced online education and self-regulation. Dubuc-Charbonneau and Durand-Bush (2015) define self-regulation as an “individual’s capacity to plan, control, evaluate, and adapt thoughts, feelings, and behaviors to achieve personal goals" (p. 175). This ability is manifested in educational settings as self-regulated learning (SRL), by which students do more than merely complete the course material at their own paces (which can lead to procrastination and last-minute cramming). Rather, self-regulated learners succeed by managing course material effectively in all its forms. The three components of SRL are (1) cognitive strategies, such as setting goals, planning ahead, and constantly monitoring and reflecting on the learning process; (2) emotional variables, and the ability to promote emotions that are supportive to learning; and (3) motivational variables. Of these, Cho and Heron (2015) found that emotional and motivational variables predicted success in an online self-paced course better than mastery of cognitive strategies. Thus, the wise instructional designer will construct such courses to promote helpful emotions and propagate the motivation to succeed. This can be done by (1) intentionally programming the student-instructor interaction (a strong interaction, as Rhode (2009) reported); (2) building system-generated feedback based upon student performance, and (3) having students complete an orientation to acclimate to the course before beginning their studies of its content.

Online Education in Optometry

From the previous consideration of current self-paced education and multimodiality theory in cranial nerve andragogy, it is clear that computer- and online-based educational components are the topic *du jour*. Since analyses of the scope and use of online education are widely available, the focus of this review will turn to a subset of online education: its implementation in optometric education.

LMS implementation. There are few examples of online education in the optometric literature. Of those that exist, the earliest describe the minutia of implementing a LMS upon an existing optometric course or curriculum. The first such records of LMS implementation were published in 2004. Mozlin and Perry (2004) and Nowakowski and Swanson (2004) both implemented the *WebCT* LMS in their colleges, the State University of New York (SUNY) State College of Optometry and University of Alabama-Birmingham School of Optometry (UAB), respectively. At SUNY, the didactic faculty were trained on *WebCT*, and used it to at least host their course syllabi and lecture presentations. Some ambitious faculty members experimented with the more innovative features, like LMS-based interactive lessons. At UAB, *WebCT* was similarly used to host course content, but also to administer tests, grades, and accept assignments. Faculty at both sites reported that the initial course redesign for *WebCT* was time-consuming, and UAB faculty reported technical difficulty with the assignment submission function. However, all SUNY faculty members planned on continuing the use of their LMS components in future years. Interestingly, 64% of the SUNY faculty reported that *WebCT* implementation led them to rethink or redesign their course content.

Another example uses a LMS to enhance clinical externships. Fourth-year optometry students use a portion of their final year of study to train in various external clinical sites, a process called externship. This useful program provides a specialized clinical experience that is potentially more akin to actual private practice optometry than what is found in the college clinic. However, there are challenges that arise from students being separated from their programs and colleagues. For example, externs often experience both social and administrative isolation, which can lead to academic disengagement during the externship. To combat this and other problems, Peterson-Klein et al. (2004) successfully used *WebCT* to enhance the externship experience. LMS-based patient quizzes replaced patient logs (which were previously recorded on paper and mailed to the optometry program). An asynchronous discussion board hosted on *WebCT* gave fourth-year students a common forum for peer discussion of clinical cases. Qualitative evaluations of this supplementary program were generally positive.

Some programs chose to create their own LMSs—at least initially—as a proof-of-concept before investing in expensive systems. Bailey (2006) of the University of Houston College of Optometry developed his own personal course website using HTML-authoring software. Though only a LMS in the loosest sense, it did host his syllabi, audiovisual lectures, and course calendar. Schwartz et al. (2006) developed the proprietary website *BACIC* to host text-based clinical case studies for a first-year course in an attempt to integrate basic science and clinical knowledge. The cases were organized along with pertinent discussion topics on an asynchronous message board. However, the response to this innovative resource was not positive. Student focus groups suggested the online message board should be replaced with face-to-face discussion because their online discussions did not resemble a true exchange of ideas, and that the case-based learning was too advanced for their limited clinical knowledge.

Chu and Borsting (2009) adjusted Schwartz et al.'s (2006) technique by addressing its reported criticisms. Rather than using a proprietary LMS, their clinical case studies were hosted on the commercially-available *Blackboard* LMS which, in an improvement over the *BACIC* website, was able to host multimedia content, including text, pictures, and video. Also, learning cases were presented to third-year optometry students—who have some limited clinical experience—rather than the relatively inexperienced first-year students of Schwartz et al. (2006). To encourage discussion on case-related asynchronous message boards, Chu and Borsting (2009) preemptively oriented students on what constitutes useful discussion in a message board context. Despite these alterations, a quantitative evaluation of education outcomes found no effect on either clinical ability or didactic performance, though the authors indicate this is not unusual in such studies. Upon qualitative review, students expressed generally positive attitudes regarding the multimedia components of the cases. The elements that were perceived as being most useful were the clinical cases, and the message board items that involved clinical diagnosis and treatment.

Laboratory preparation. More recent examples of online education in optometry include Goodwin et al. (2014), who used the open-source *Moodle* LMS to run blended learning laboratory preparation modules, and Sanchez-Diaz (2013) and Resuehr et al. (2014), who used technological resources such as *YouTube* videos, computer applications, and video podcasts for the same purpose. Though no improvement was found in quantifiable laboratory outcomes, students in these labs reported appreciation for the variety of materials and interactivity of the preparation process.

Other examples of optometric online education. A unique example of online education in optometry was published by Whiteside et al. (2015), who taught medical billing and coding to third-year optometry students using clinical cases. Students who completed their online, case-based course in coding performed better on evaluative coding cases than students who received traditional lecture-based training only. The fact that no mention is made in this study of a LMS indicates the nearly complete level of acceptance of the technology in present-day optometric education.

Though Nowakowski and Swanson mentioned the possibility of sharing online course content between optometry programs as early as 2004, no example of such an initiative was found in the optometric literature until recently. Taylor et al. (2015) developed a distance education course in which *Neuroanatomy* course lectures given at SCO were recorded and asynchronously hosted on the *Tegrity* video capture website. Students at Michigan College of Optometry (MCO) were given access to these online lectures as the primary content of their *Neuroscience* course. The instructor of record at SCO hosted live videoconference sessions with the MCO students once a week to answer questions and provide guidance. Statistical analysis of the first two years of this course showed statistically-equivalent final examination outcomes between students who received the course material in person (i.e., SCO students) and those who received it asynchronously (i.e., MCO students) (Taylor et al., 2015).

Critical Thinking and Clinical Thinking

The various innovations discussed to this point all purport to improve the educational experience but, as is evident, the results of many such interventions either do not include quantitative evaluation of educational outcomes or fail to demonstrate a quantitative effect (Chu & Borstag, 2009; Goodwin et al., 2014; Peterson-Klein et al., 2004; Resuehr et al., 2014; Southard et al., 2015; Taylor et al., 2015; Yeung et al., 2012). Successful examples include the virtual patients of Johnson et al. (2013) and Johnson et al. (2014), Whiteside et al.'s (2015) billing and coding course, and Svenningsen and Pear's (2011) critical thinking evaluation. The latter example presents a possible common link: all the quantitatively-successful interventions listed here presented course material so that critical thinking was essential for its mastery. Perhaps the subject of critical thinking—and its optometrically-applicable corollary, clinical thinking—is worth additional consideration.

Critical thinking. Critical thinking has been extensively examined in educational literature over the past several decades. It has been defined as "purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological and contextual considerations upon which judgment is based" (Facione, 1990, p. 2). In his review of theories and controversies in critical thinking, Dunne (2015) documents this phenomenon in governmental policy and higher education, summarily stating that "…critical thinking has been heralded for quite some time as being one of the most desirable outcomes of higher education" (p. 86), both for its practical occupational utility as well as its potential for driving lifelong learning. Since both of these outcomes are of importance to optometric practice, it is perhaps no surprise that optometric education has also resoundingly discussed and embraced the necessity of teaching and practicing critical thought (Association of Schools and Colleges of Optometry [ACOE], 2011; Elder & Paul, 2008; Galvin, 2008; Hoppe, 2008).

There is considerable research available concerning the nature of critical thinking itself. As a disposition, it is naturally more developed among participants in less practical fields of study—like arts and humanities—than in practical professions (Walsh & Hardy, 1999), although an active critical thinking disposition has been linked to occupational satisfaction in nursing (Kim, Moon, Kim, Kim, & Less, 2014). In optometric education, critical thinking has been correlated to clinical ability, though neither critical thinking skills nor dispositions improve from clinical experience or service-learning participation (Denial, 2008a, 2008b; Denial & Pitcher, 2007; Nokes, Nickitas, Keida, & Neville;

2005). Academically, Williams, Schmidt, Tilliss, Wilkins, and Glasnapp (2006) and Denial and Pitcher (2007) determined that critical thinking skills and dispositions were strongly predictive for performance on dental and optometric national board examinations, respectively.

Though the clinical utility of critical thinking has been demonstrated, the body of literature concerning its andragogy is suspect. There are many studies and reviews published in the health professions and optometric literature reporting critical thinking improvements due to novel instructional techniques (Chit Ming, 2014; Clegg et al., 2014; Cook & Triola, 2009; Forneris & Peden-McAlpine, 2007; Santiago, 2011; Wilgis & McConnell, 2008; Wyles et al., 2013) or overarching course- or curricular-wide redesign (Good, Earley, & Nichols, 2011; McLaughlin et al., 2014; Nehmad & Appel, 2011; Yuan, Williams, & Fan, 2008). This evidences the industry-wide enthusiasm for the development of critical thought. Yet, as indicated in several literature reviews and meta-analyses, the results from these studies are often variable and not repeatable, and therefore do not clearly define an andragogical method. The variations can be explained by (1) differences in research design, (2) implementation of instructional interventions, (3) durations of study, (4) assessment measures used, and (5) sample sizes.

The literature on effective critical thinking andragogy could be improved by performing well-designed research with randomized selections into large treatment and control groups (or robust study design when randomization is not possible), use of standardized assessment instruments for quantitative measures, and an intervention duration of at least twelve weeks that contains explicit instruction in critical thinking skills (Behar-Horenstein & Niu, 2011; Facione, 1990; Niu et al., 2013; Lai, 2011;

Tiruneh et al., 2014; Yuan et al., 2008). Such research would benefit the education profession and discipline at large by helping determine how to teach critical thinking in higher education effectively and efficiently (Dunne, 2015).

High-quality clinical ability requires high-quality critical thinking, but health professions students tend to have difficulty developing this important skill (Niu et al., 2013; Walsh & Hardy, 1999). In optometric education, the need for students to practice critical thinking is well understood by the administrators, faculty, and governing bodies, as seen in the ASCO (2011) graduate attribute statement.

Clinical thinking. Though critical thinking is widely studied and discussed in the medical and health professions' fields, clinical thinking is perhaps more important. Clinical thinking is a complex process that begins with recall and understanding of both a foundational body of knowledge and each individual patient's clinical presentation. The astute clinician aptly exploits this fundament to both arrive at an accurate diagnosis and decide upon the most effective treatment to pursue, a process called clinical reasoning. Finally, this clinical reasoning is subjected to self-review via critical thinking (Faucher, 2011). Examples of these concepts in a clinical setting are found in Table 1.

Of these clinical thinking steps, effective clinically-oriented andragogy in pre-clinical settings must necessarily focus upon its academic elements (i.e., knowledge acquisition, theories of clinical judgment, and general critical thinking). In contrast, patient-centric elements, such as assessment and evaluation of individual circumstances and values, can only be mastered with direct patient interaction in the clinic (Facione & Facione, 2008; Faucher, 2011; O'Neill & Dluhy, 1997).

Though important, there have been fewer studies on clinical thinking than critical

Table 1

Example of Clinical Thinking in Clinical Practice

History/Findings	Clinical Thinking	
A 20 year-old man presents with pain and redness left eye; he is wearing sunglasses indoors	Clinical reasoning: • Mental representation of the clinical case by hypothesis generation	Pain, hyperemia, sensitivity to light Anterior uveitis? Corneal erosion? Contact lens related complication? Corneal ulcer? Other ocular health problem?
	Decision-making	Additional questions to ask Procedures to do: visual acuity, pupils and slit lamp examination (carefully examine cornea and look for cells and flare in anterior chamber)
	Clinical reasoning: • Expectations	Visual acuity probably reduced; left pupil may be smaller; limbal injection, possible corneal involvement; cells and flare may be present
	Critical thinking	Do I consider all the possibilities given the available information? What if expectations are not confirmed by clinical data?

Note. Adapted from "Differentiating the Elements of Critical Thinking," by C. Faucher, 2011, *J Optometric Ed, 36*(3), p. 143. Retrieved from http://journal.opted.org/articles/Volume_36 _Number_3_CriticalThinking.pdf Copyright 2011 by the Association of Schools and Colleges of Optometry.

thinking, due to its relative boutique status in health care education. Seif et al. (2013) created a module on clinical reasoning for physical therapy students, which they hosted on their university's *Moodle* LMS. The module contained video footage of a mock examination, related thought questions, and Internet searches for related resources. At the end of the module, students used what they had learned to create an appropriate exercise plan. Analyses of clinical reflection and clinical reasoning showed significant improvements in 17 of the 26 subcategories of clinical reflection and reasoning, implying that intentionally-designed lessons can have a positive effect on clinical thought.

Summary

Multimodiality theory in education arose with the technological innovations of the Internet and computer ages (Jewitt, 2012). Of the many resources that have been developed, some have been used to teach cranial nerve concepts and their assessment as part of medical and health professions courses. These include computer atlases (Nowinski & Chua, 2013; Nowinski at al., 2012; Nowinski et al., 2015; Richardson-Hatcher et al., 2014), online videos (Azer et al., 2012; Latha et al., 2011), and patient simulations (Johnson et al., 2013; Johnson et al., 2014; Wang et al., 2012; Wang et al., 2014; Willis & Van Sickle, 2015), of which only the virtual patient simulations of Johnson et al. (2013) and Johnson et al. (2014) have demonstrated improved outcomes.

Online education is well designed for self-paced lessons, which often are hosted on LMSs (Betihavas et al., 2015; Brinkman et al., 2007; McLaughlin et al., 2014; Pear & Crone-Todd, 1999). Self-pacing allows for students to complete course material at schedules convenient to them. Self-paced lessons and courses have been designed according to the behaviorist PSI system (Svenningsen & Pear, 2011) and the constructivist equivalency theorem (Southard et al., 2015). In optometric education, various online applications have been introduced, from LMSs (Mozlin & Perry, 2004; Nowakowski & Swanson, 2004) to the development of online self-paced multimodal lessons (Chu & Borsting, 2009; Goodwin et al., 2014). Though innovative and modern, the results of these initiatives are often mixed (Goodwin et al., 2014; Schwartz et al., 2006).

Critical thinking and its corollary, clinical thinking, may provide the key for understanding appropriate online self-paced design. By using the multimodal capabilities of the Internet and personal computers, lessons can be intentionally designed, hosted, and presented so that a student's critical thinking is stimulated and developed (Facione & Facione, 2008; Faucher, 2011; O'Neill & Dluhy, 1997).

Chapter 3: Methodology

Participant selection, instrumentation, data collection, and data analysis procedures for this study were developed in order to yield illustrative results relative to the four research questions. There were two main phases to the study: *part I*, which contained both quantitative and free-response elements; and *part II*, which consisted of interviews. This chapter will review each of the developed methodological components and how they were implemented.

Participant Selection

The pool of potential participants in this study was composed of the 136 current SCO first-year students. This population was predominantly Caucasian and female, ranging in age from 21 to 40. All students had completed undergraduate courses in chemistry, organic chemistry, biology, physics, psychology, and statistics, and nearly all had earned a Bachelor's degree. The mean entering undergraduate GPA of the potential sample was 3.53 (SCO, 2015c).

All members of the class had the opportunity to participate in part I of the study as a required assignment in their *Neuroanatomy* course. Thus, non-random convenience sampling was used for its quantitative element and criterion sampling for its survey element. The *Understanding the Cranial Nerves* intervention was hosted on the *Neuroanatomy* course's *Moodle* page as a required component of that course. Part I participants were recruited via an online letter embedded in the *Understanding the Cranial Nerves* intervention, which is reproduced in Appendix B. Students accessed the letter prior to beginning the intervention. The letter instructed those interested in participating to review the part I informed consent document—reproduced in Appendix

C—which was linked to the recruitment letter. At the end of the recruitment letter, students responded to an on-screen forced choice item, for which they could either opt in or opt out of the study. Those who opted in will hereafter be referred to as *participants*. Though all students were required to complete the intervention for the course, only the depersonalized, anonymous results from participants were used in this study. The inclusion criterion for part I was mere willingness to participate in the study, while exclusion criteria were lack of willingness to participate and failure to complete all components of the intervention.

All members of the class who completed part I of the study were given the opportunity to participate in part II. Participants for this phase were recruited via a bulk e-mail message with an attached recruitment letter (see Appendix B). The part II sample was comprised of the first eight respondents who scheduled an interview with the lead investigator, making it a criterion sample. Part II participants received, read, and agreed to an informed consent (see Appendix C) at the beginning of their individual interview sessions. Inclusion criteria for part II were completion of the *Understanding the Cranial Nerves* intervention as part of the *Neuroanatomy* course in the fall semester of 2015, willingness to participate, promptness of reply to initial queries, and compatibility with the researcher's schedule. Exclusion criteria included a failure to complete the intervention as described, disinclination to volunteer, slow response to initial recruitment messages, and incompatibility with the researcher's schedule.

Instrumentation

The researcher developed several instruments to assess the research questions. These included a pre-/post-test—reproduced in Appendix D—to determine knowledge acquisition, an attitude survey (Appendix E) and semi-structured interview protocol (Appendix F), which both determined participants' opinions of the intervention.

Pre-/post-test. The pre-/post-test is a quantitative 8-item test, of which 5 items are multiple-choice, one requires arrangement of options into an appropriate order, one requires selection of *all* correct answers (a multiple-selection question), and one requires matching correct answers from each of two lists (see Appendix D). Six of the 8 items—items 3 through 8—require clinical thinking to determine the correct answer, as the clinical question in each is based upon reasonable implications that can be drawn from the intervention content. The instrument is scored 0 to 8, based upon the number of correct answers (as indicated by underlined text in Appendix D).

At its most basic, the pre-/post-test served to measure factual recall and clinical thinking ability. Its presentation prior to and after the intervention content allowed for analysis of the intervention effect via quantitative comparison of pre-test and post-test results, which reflect the extent the course material was learned. Since SCO students are bound by the dictates of the SCO honor code, the researcher merely requested that participants complete the pre-/post-tests individually, without attempting to actively police them for compliance (SCO, 2015a).

Since the pre-/post-test instrument was developed specifically for *Understanding the Cranial Nerves*, it lacks criterion-related validity. However, it has strong content validity, due to its development and formative evaluation according to the rigorous *Morrison, Ross, Kalman, and Kemp* (*MRKK*) instructional design model, and review by three expert faculty members at SCO (Lunenburg & Irby, 2008; Morrison, Ross, Kalman, Kemp, 2013). In the development process, the subject-matter expert—who is also the instructor of record of the *Neuroanatomy* course and the investigator for this study—first identified the eight learning objectives (Table 2) for the instructional intervention and developed the course content around them. The pre-/post-test items were developed so that each one assessed a specific learning objective. After development of the intervention, two additional SCO faculty members, experienced clinicians both, reviewed its content for accuracy and clarity. In addition to advice about the course content, the experts also provided suggestions for improvement of some of the pre-/post-test items, which were implemented.

As part of the formative evaluation for the intervention, six second-year students completed all its components. To determine split-half reliability for the instrument, the researcher used *IBM SPSS 23* to compare results from items 1, 2, 3, and 5, against results from items 4, 6, 7, and 8. These items were chosen to make the halves of the instrument as equivalent in difficulty as possible: each contains one item that was commonly answered correctly (i.e., one each of items 1 and 8), two more difficult multiple choice items (i.e., two each of items 2, 3, 6, and 7), and one question graded on a partial credit scale (i.e., one each of items 4 and 5). The Spearman-Brown adjusted Pearson r correlation coefficient for the two halves of the post-test was 0.689—indicating moderately-strong split-half reliability—but fell to 0.206 when comparing the halves of the pre-test. The poor pre-test split-half reliability likely reflects the sporadic nature of the second-year participants' clinical knowledge of the cranial nerves (Hinkle, Wiersma, & Jurs, 2003; Lunenburg & Irby, 2008).

Attitude survey. The attitude survey instrument is an opinion survey with nineteen 5-choice Likert-type items and 2 free-response items (see Appendix E).

Table 2
Learning Objectives for Understanding the Cranial Nerves.

Objective	*Classification Type*	*Performance Type*	*Pre-/Post Test Item**
1. *Based on an online presentation, identify any of the three general rules of cranial nerve assessment with 100% accuracy.*	Rule	Recall	Item #1
2. *Given a list of possible clinical symptoms, identify those that imply neurological involvement with 80% accuracy.*	Concept	Recall	Item #2
3. *Given a description of a clinical case, identify the masquerader condition that is most likely to be present, with 100% accuracy.*	Principle	Recall	Item #3
4. *After reviewing a list containing the content, reproduce the order in which cranial nerves are tested, with 80% accuracy.*	Concept	Recall	Item #4
5. *Given a case with pupillary testing results, choose the correct diagnosis, with 100% accuracy.*	Principle	Application	Item #5
6. *Given a case with eye movement information, select the appropriate diagnostic action and its rationale, with 100% accuracy.*	Principle	Application	Item #6
7. *After reviewing a clinical case, indicate the nature of a facial nerve palsy, with 100% accuracy.*	Principle	Application	Item #7
8. *Given a clinical case with cranial nerve testing, identify the abnormal finding and its clinical implication, with 100% accuracy.*	Concept	Application	Item #8

Note. *Classification types* and *performance types* are based upon the expanded performance-content matrix (Merrill, M. D. (1983). Component display theory. In C. M. Reigeluth (Ed.). *Instructional design theories and models: An overview of their current status* (pp. 282-333). Hillsdale, NJ: Erlbaum.)
*Refer to Appendix D for text of pre-/post-test items.

Likert-type items can be answered from 1 (*strongly disagree*) to 5 (*strongly agree*). The researcher developed one free-response and 13 Likert-type items to elicit feedback about the intervention content, while the remaining one free-response and 6 Likert-type items elicit feedback about the user interface and aesthetics of the intervention.

Each item of the attitude survey was scored separately. Higher numbers on Likert-type items implied more agreement with the statement in question. Upon analysis, the researcher reviewed free-response feedback across all respondents to search for common ideas, and among individual respondents for notable minority positions. The attitude survey served to investigate and denote students' feelings and thoughts about *Understanding the Cranial Nerves*, its content, and its usability. It occurred at the end of the intervention, after all other content had been completed.

The attitude survey instrument was developed specifically for *Understanding the Cranial Nerves* according to the *MRKK* model (Morrison et al., 2013). The instructional designer developed Likert-type items based upon his understanding of salient points regarding the content, aesthetics, and usability of the intervention. The instructional designer's professor at the time of development gave feedback on the survey instrument and approved its final form, granting it considerable content validity.

Since there are two different types of data in the attitude survey, two types of reliability must be discussed. For free-response data, in which students can enter any feedback they like, it is important that all those evaluating the data agree on how to interpret it, a ranking called interrater reliability. In this case, there is only one rater—the researcher—so interrater reliability of the free-response data is 100% by default (Hinkle et al., 2003; Lunenburg & Irby, 2008).

For Likert-type item data, it is important to assure that different items report equivalent data or, in other words, that the data has strong internal consistency reliability. Since there are two subscales on this instrument, reliability must be determined for the data of each. In this case, Chronbach's *alpha* coefficient was calculated in *IBM SPSS 23*, with data from the six students involved in the formative evaluation process. The *alpha* coefficients for the *Content and Instruction* and *Aesthetics and Usability* subscales were .148 and .150, respectively, indicating weak internal consistency reliability. Interestingly, if items 1 and 17 are disregarded, the *alpha* coefficients increase to .968 and .762 for each respective subscale. However, the small number of Likert-type items per subscale and small sample size of the formative evaluation preclude the drawing of too definite a conclusion from this result. The larger sample size in part I of the proposed research helped determine the reliability of the Likert-type items with greater accuracy (see Chapter Four, Additional Analysis, for further information) (Hinkle et al., 2003; Lunenburg & Irby, 2008).

Interview protocol. The interview protocol instrument provides a semi-structured outline for the performance of interviews (see Appendix F). It contains eight questions that assess the impact of *Understanding the Cranial Nerves* on students' perceptions of their academic ability and outcomes in the *Neuroanatomy* course. The instrument is not completely descriptive, however: at the interviewer's prerogative, other pertinent questions may be asked to elucidate meaning.

As the interviews were performed, the interviewer recorded participants' comments by hand on the protocol sheet, as accurately as possible. The researcher analyzed these responses across all respondents to search for common ideas, and among individual respondents for notable minority positions.

The interview protocol instrument was specifically developed for this study according to the *MRKK* model (Morrison et al., 2013). The questions were designed to determine the perceived impact of the intervention on many aspects of academic life at SCO, but this is the limit of its content validity.

As previously explained, interrater reliability is the pertinent measure of the data gleaned from the interview protocol. Since the researcher is both the only interviewer and only rater of interview data, interrater reliability for this instrument is 100% (Hinkle et al., 2003; Lunenburg & Irby, 2008).

Data Collection

Data for this research were obtained in two parts:

- Part I: Participants completed *Understanding the Cranial Nerves* between October 27th and November 5th of 2015 as a graded assignment for their *Neuroanatomy* course work at SCO. In doing so, they completed the pre-/post-test instrument (see Appendix D) twice, once before the intervention and once afterwards, to determine the extent to which they understood the course objectives at either time. Participants also completed the attitude survey after finishing the intervention (see Appendix E).
- Part II: Part I participants were given the opportunity to volunteer for an interview in January of 2016. Students were recruited after their final course grades for *Neuroanatomy* were finalized and irrevocable. Only the first eight students to both respond to the recruitment letter and schedule an interview were selected as part II participants. The investigator scheduled convenient times for one-on-one

interviews and completed the semi-structured interview protocol (see Appendix F) for each participant.

To prevent participants' grades and opinions from being publically exposed, the researcher randomly assigned ID numbers for each, and kept identification keys in a separate, password secured computer file. Participant names were not used during data analysis or anywhere in this report or others.

Data Analysis

In this study, the quantitative academic data, survey data, and interview data obtained from the previously-described instruments were analyzed as follows:

1. Participant grades on pre-test and post-test instruments were entered into *IBM SPSS 23*. The changes from pre-test to post-test grades were evaluated via a one-tailed, one-sample Student's *t*-test to determine whether a significant improvement in factual recall performance was present in the treatment group. Scores on pre-/post-test clinical thinking items were evaluated in the same manner, to determine the presence or absence of improvement in clinical thinking performance. Cohen's formula was used to calculate effect sizes for each variable.
2. Free-response survey results were reviewed by the researcher, who identified commonly-held and interesting ideas from the responses. The resulting data was reported in order to give an accurate view of students' opinions of the aesthetics, usability, and content of *Understanding the Cranial Nerves*, as they existed immediately after the intervention's completion.
3. Likert-type feedback was entered into *IBM SPSS 23* and evaluated for

exceptional results using Pearson *chi*-squared goodness-of-fit tests. The expected distribution for this test was estimated based upon previous experience with student participants, who often answer Likert-type items with the maximum value response; and the knowledge that *Understanding the Cranial Nerves* had undergone extensive formative evaluation. Thus, in the goodness-of-fit test, it was assumed most responses would be the highest value.

4. Interview results were reviewed by the researcher, who identified commonly-held and interesting ideas as they were presented. The researcher reported the resulting data so as to give an accurate view of students' opinions of the intervention's academic utility, as they were approximately two months after the completion of the *Neuroscience* course.

Summary

Study participants were recruited from the first-year student population at SCO. When part I participants completed the intervention as a requirement of the *Neuroanatomy* course, their pre-test, post-test, and attitude survey results were recorded. Part II participants were interviewed according to a pre-defined semi-structured protocol. The resulting data from each instrument was analyzed to clarify the stated research questions, and (when applicable) to reject or accept the null hypotheses.

Chapter 4: Results

This study was designed to examine the utility of the *Understanding the Cranial Nerves* instructional intervention in first-year optometric education. By following the methodology described in Chapter 3, a wide assortment of data was collected and analyzed using appropriate quantitative methods. Nominative data were probed informally for interesting information. The results of these analyses are presented here.

The first section of this chapter contains statistics that describe the nature of the accumulated data. The second section contains analyses of how these data relate to the four research questions and three null hypotheses. The third section contains the results of a statistical analysis to reinforce the questionable reliability of the attitude survey. Though important, this latter analysis does not directly relate to one of the research questions and, as a result, is not included in those discussions. A summary of the content will conclude the chapter.

Descriptive Statistics

Part I variables. Of the 136 first-year students who took *Understanding the Cranial Nerves* as part of their *Neuroanatomy* course, 71 opted in to this study via the online recruitment letter (see Appendix B). Their mean pre-/post-test scores and standard deviations are listed in Table 3, along with the mean change in scores from pre-test to post-test and standard deviations of that change. Table 4 contains the same descriptive statistics, but for the 6 clinical thinking items (items 3 through 8) only. Descriptive statistics for the attitude survey include mean values and standard deviations for responses to Likert-type items, and are found in Table 5. Only 17 and 18 participants answered the first and second free-response questions of the attitude survey, respectively.

Table 3
Mean Scores and Standard Deviations for Pre-Test, Post-Test, and Change from Pre-Test to Post-Test

Instrument	$\bar{X}$	s
Pre-test	3.75	.92
Post-test	6.12	.92
Δ	2.37	1.20

Note. $n = 66$. 5 participants were excluded for failing to complete either the pre-test or post-test. Maximum possible score on either pre-test and post-test is 8.00.

Table 4
Clinical Item Score Means and Standard Deviations for Pre-Test, Post-Test, and Change from Pre-Test to Post-Test

Instrument	$\bar{X}$	s
Pre-test$_{clinical}$	1.80	.90
Post-test$_{clinical}$	4.17	.91
$\Delta_{clinical}$	2.37	1.19

Note. $n = 66$. 5 participants were excluded for failing to complete either the pre-test or post-test. Maximum possible score on either pre-test$_{clinical}$ and post-test$_{clinical}$ is 6.00.

The researcher excluded some outliers when necessary to avoid skewing the results. 10 participants did not complete the attitude survey, and 5 did not complete either the pre-test or post-test. These participants' results, such as they were, were excluded from the analyses of the instruments in question.

Part II variables. The interviewer completed 8 one-on-one interviews according to the methodology in Chapter 3. Each interviewee responded to every question on the interview protocol. The mean, median, and modal interview durations were 13.625, 15, and 15 mins, respectively. The minimum time spent in the interview process was 8 mins (by interviewee 8) and the maximum time, 19 mins (by interviewee 6).

Testing the Research Questions

The four research questions developed for this study are:

1. To what extent does completion of a self-paced, online cranial nerve

Table 5

Means and Standard Deviations of Response Values on Attitude Survey Likert-Type Items

Statement	$\bar{X}$	s
Content and Instruction		
C1. The content was easy to read and understand.	4.52	.72
C2. The embedded media were easy to follow and helpful.	4.64	.63
C3. In your opinion, the content is applicable to clinical practice.	4.77	.53
C4. In your opinion, the content is applicable to critical thinking.	4.84	.37
C5. All pertinent information was covered in the module.	4.67	.57
C6. Sufficient information was provided to meet the learning objectives.	4.61	.59
C7. The content was helpful in understanding the scientific background behind cranial nerve organization.	4.72	.45
C8. The content was helpful in understanding the scientific background behind cranial nerve assessment.	4.77	.46
C9. The content was helpful in understanding the scientific background behind cranial nerve treatment.	4.57	.69
C10. The content was helpful in understanding how to perform basic cranial nerve testing in the optometric clinic.	4.80	.44
C11. The instruction would be useful if presented in OPT 113 (Neuroanatomy) course.	4.69	.56
C12. The instruction would be useful if presented during clinical practice.	4.74	.51
C13. My courses at SCO adequately prepared me to understand the course material.	4.67	.60
Aesthetics and Usability		
A1. The overall design of the instruction was attractive.	4.02	1.01
A2. The layout of the elements (e.g.: menu bar, content frame) was useful.	3.84	1.17
A3. The instruction design maximized ease-of-use.	3.75	1.12
A4. The color scheme was attractive.	3.95	1.06
A5. The graphics were attractive.	4.11	.97
A6. The text was readable.	4.75	.47

Note. $n = 61$. 10 participants were excluded for failing to complete the attitude survey. The best possible response on any statement is a 5.

intervention improve factual recall among first-year optometry students?

1. To what extent does completion of a self-paced, online cranial nerve intervention improve clinical thinking ability among first-year optometry students?
2. What are the perceptions of first-year optometry students about a self-paced, online cranial nerve intervention immediately after completing it?
3. What are the perceptions of first-year optometry students about a self-paced, online cranial nerve intervention after finishing the course that contained the intervention?

The researcher investigated these questions using a variety of statistical and non-statistical means. For the first and second research questions, one-sample Student's t-tests were used to evaluate the mean changes in score from the pre-test to the post-test. The first *t*-test analyzed the change across the pre-tests and post-tests for all eight items, and the second for the six clinical thinking items alone. The level of significance was set at $p = .05$ for these tests. Since mean improvement was noted in both cases (see Tables 3 and 4), it is therefore reasonable to assume that the intervention would lead to generally improved scores. Thus, the researcher decided upon one-tailed *t*-tests, and disregarded the possibility that scores might decrease from pre-test to post-test. To determine the effect sizes of any significant findings, Cohen's *d* statistic was calculated as needed.

For the third research question, the researcher (1) performed a Pearson *chi*-squared goodness-of-fit test on each of the nineteen Likert-type items, to determine if the frequency of different responses on the 5-value ordinal scale varied significantly from an expected distribution; and (2) read through the free-response items multiple times, identifying common and outstanding ideas and concerns. The level of significance for the Pearson *chi*-squared goodness-of-fit test of research question three was set at $p = .01$, to better distinguish only those frequency distributions strongly variable from the expected distribution. The second technique used for research question three is similar to the process used to evaluate the interview data of research question four.

Research question 1. The first research question reads: "To what extent does completion of a self-paced, online cranial nerve intervention improve factual recall among first-year optometry students?" To answer this, the researcher analyzed the sample's mean change on scores (see Table 3) for the eight-item pre-test to the identical post-test, using a one-sample Student's *t*-test. The *t* statistic expresses, in terms of standard deviations, the difference between the sample mean and the mean of the population from which it was drawn. The population mean was set at 0, in order to compare the change in scores from the sample to no change at all. Results of the test are reported in Table 6.

The null hypothesis for this research question was that factual recall of cranial nerve content is not improved by the completion of a self-paced, online cranial nerve intervention among first-year optometry students. Put symbolically for the purpose of the statistical test:

$$H_0: \mu_\Delta \leq 0$$

Since the desired result was merely a significant improvement (which would imply that learning had occurred), the alternate hypothesis was stated symbolically as:

$$H_a: \mu_\Delta > 0$$

A significant change in scores from pre-tests to post-tests [t (65) = 15.984, p <

Table 6
Results of One-Sample Student's t-tests for Mean Changes from Pre-Test to Post-Test, for All Items and Clinical Thinking Items Alone

Score	n	t	df	*sig*	*Mean Diff.*
Δ	66	15.984	65	*	2.37
$\Delta_{clinical}$	66	16.115	65	*	2.37

Note. $\alpha = .05$ *Effect is statistically-significant at a level less than .001.

.001] was found in the study sample, compared to the assumption of no change. The null hypothesis was rejected and the alternate hypothesis was accepted.

Since a statistically-significant effect was found, it was useful to determine the effect size (*d*). According to Cohen's formula (and using data from Table 3):

$$d = \frac{\bar{X}_\Delta - \mu}{s}$$

$$= \frac{2.37 - 0}{1.20}$$

$$= 1.98$$

which is considered a large effect size (Hinkle et al., 2003).

Research question 1 is answered: this self-paced, online cranial nerve intervention significantly improves factual recall among first-year optometry students, with a large effect.

Research question 2. The second research question reads: "To what extent does completion of a self-paced, online cranial nerve intervention improve clinical thinking ability among first-year optometry students?" To answer this, the researcher analyzed the sample's mean change in clinical thinking scores (see Table 4) from the pre-test to the post-test, using a one-sample Student's *t*-test. As it was for the first research question, the population mean was set at 0, to compare the change in scores from the sample to no change. Results of the test are reported in Table 6.

The null hypothesis for this research question was that clinical decision making regarding cranial nerve assessment is not improved by the completion of a self-paced, online cranial nerve intervention among first-year optometry students. Put symbolically for the purpose of the statistical test:

$$H_0: \mu_{\Delta clinical} \leq 0$$

Since the desired result was a mere significant effect (which would imply that learning had occurred), the alternate hypothesis was stated symbolically as:

$$H_a: \mu_{\Delta clinical} > 0$$

A significant change in clinical thinking scores from pre-tests to post-tests [t (65) = 16.115, p < .001] was found in the study sample, compared to the assumption of no change. The null hypothesis was rejected and the alternate hypothesis, accepted.

Since a statistically-significant effect was found, it was useful to determine the effect size (d). According to Cohen's formula (and using data from Table 4):

$$d = \frac{\bar{X}_{\Delta clinical} - \mu}{s_{\Delta clinical}}$$

$$= \frac{2.37 - 0}{1.19}$$

$$= 1.99$$

which is considered a large effect size (Hinkle et al., 2003).

Research question 2 is answered: this self-paced, online cranial nerve intervention significantly improves the clinical decision making of first-year optometry students, with a large effect.

Research question 3. The third research question reads: "What are the perceptions of first-year optometry students about a self-paced, online cranial nerve intervention immediately after completing it?" To answer this, 21 items of survey data were analyzed from the attitude survey instrument. 19 of these items were Likert-type with an ordinal 1 to 5 scale, and 2 were free-response items.

Likert-type items. For the Likert-type items, the researcher ran a Pearson *chi*-squared goodness-of-fit test for each: 19 in all. The test variable χ^2 indicates how well the frequency distribution of answers for an item meets an expected frequency distribution. Given 61 respondents, expected results were 1 (1.64%) answering choice "1 (*strongly disagree*)," 3 (4.92%) answering choice "2," 5 (8.20%) answering choice "3," 7 (11.48%) answering choice "4," and 45 (73.77%) answering choice "5 (*strongly agree*)," for any particular item. Table 7 contains the results of this analysis.

There is a separate null hypothesis for each Likert-type item analyzed by the Pearson *chi*-squared analysis. Each one reads that the frequency distribution of the item is the same as the expected frequency distribution. The alternative hypothesis is that there is, in fact, a difference.

Items that differed significantly from the expected frequency were C1 [χ^2 (4) = 14.705, p = .005], C6 [χ^2 (4) = 22.641, $p < .001$], C7 [χ^2 (4) = 23.308, $p < .001$], A1 [χ^2 (4) = 39.975, $p < .001$], A2 [χ^2 (4) = 42.476, $p < .001$], A3 [χ^2 (4) = 60.476, $p < .001$], A4 [χ^2 (4) = 41.619, $p < .001$], and A5 [χ^2 (4) = 35.105, $p < .001$]. For these items, the null hypotheses were rejected.

Pearson *chi*-squared tables for each significant item's answer frequency distribution are reproduced in Table 8. The content and instruction items—C1 (*The content was easy to read and understand*), C6 (*Sufficient information was provided to meet the learning objectives*), and C7 (*The content was helpful in understanding the*

Table 7

Pearson Chi-Squared Goodness-of-Fit Results for Attitude Survey Likert-Type Items

Statement	χ^2	df	sig
Content and Instruction			
C1. The content was easy to read and understand.	14.705	4	.005
C2. The embedded media were easy to follow and helpful.	7.594	4	.108
C3. In your opinion, the content is applicable to clinical practice.	5.498	4	.240
C4. In your opinion, the content is applicable to critical thinking.	11.086	4	.026
C5. All pertinent information was covered in the module.	11.822	4	.019
C6. Sufficient information was provided to meet the learning objectives.	22.641	4	*
C7. The content was helpful in understanding the scientific background behind cranial nerve organization.	23.308	4	*
C8. The content was helpful in understanding the scientific background behind cranial nerve assessment.	10.971	4	.027
C9. The content was helpful in understanding the scientific background behind cranial nerve treatment.	12.032	4	.017
C10. The content was helpful in understanding how to perform basic cranial nerve testing in the optometric clinic.	9.041	4	.060
C11. The instruction would be useful if presented in OPT 113 (Neuroanatomy) course.	9.943	4	.041
C12. The instruction would be useful if presented during clinical practice.	9.460	4	.051
C13. My courses at SCO adequately prepared me to understand the course material.	7.771	4	.100
Aesthetics and Usability			
A1. The overall design of the instruction was attractive.	39.975	4	*
A2. The layout of the elements (e.g.: menu bar, content frame) was useful.	42.476	4	*
A3. The instruction design maximized ease-of-use.	60.476	4	*
A4. The color scheme was attractive.	41.619	4	*
A5. The graphics were attractive.	35.105	4	*
A6. The text was readable.	12.432	4	.014

Note. $n = 61$; $\alpha = .01$. *Effect is statistically-significant at a level less than .001.

Table 8

Pearson Chi-Squared Frequency Distributions Versus Expected for Significant Attitude Survey Likert-Type Items

Item	Answer	Observed	Expected	Difference
C1. The content was easy to read and understand.	1	0	1	-1
	2	1	3	-2
	3	5	5	0
	4	16	7	9
	5	39	45	-6
C6. Sufficient information was provided to meet the learning objectives.	1	0	1	-1
	2	0	3	-3
	3	3	5	-2
	4	18	7	11
	5	40	45	-5
C7. The content was helpful in understanding the scientific background behind cranial nerve organization.	1	0	1	-1
	2	0	3	-3
	3	0	5	-5
	4	17	7	10
	5	44	45	-1
A1. The overall design of the instruction was attractive.	1	0	1	-1
	2	6	3	3
	3	12	5	7
	4	18	7	11
	5	25	45	-20
A2. The layout of the elements (e.g.: menu bar, content frame) was useful.	1	1	1	0
	2	10	3	7
	3	11	5	6
	4	15	7	8
	5	24	45	-21
A3. The instruction design maximized ease-of-use.	1	0	1	-1
	2	11	3	8
	3	14	5	9
	4	15	7	8
	5	21	45	-24
A4. The color scheme was attractive.	1	1	1	0
	2	5	3	2
	3	14	5	9
	4	17	7	10
	5	24	45	-21
A5. The graphics were attractive.	1	0	1	-1
	2	5	3	2
	3	10	5	3
	4	19	7	12
	5	27	45	-18

Note. $n = 61$.

scientific background behind cranial nerve organization)—generally had more option 4 responses than expected. These extra selections were drawn relatively equally from the expected totals of the other options. On these items, the frequency distribution generally were more skewed toward higher magnitude responses than expected, which implies an overall higher level of agreement for these ideas.

Significant aesthetics and usability items—A1 (*The overall design of the instruction was attractive*), A2 (*The layout of the elements (e.g.: menu bar, content frame) was useful*), A3 (*The instruction design maximized ease-of-use*), A4 (*The color scheme was attractive*), and A5 (*The graphics were attractive*)—generally had much lower frequencies of option 5 responses than expected, with a resultant skewing of the frequency distribution toward lower scores. This indicates many participants were more reserved about these statements than would be expected.

Free-response items. Two free-response items were included in the study to allow participants to comment upon specific areas of the intervention. The first item solicited comments regarding the instructional content, to which 17 participants responded; and the second requested comments regarding the course design, to which 18 participants responded. There were 25 total participants since some responded to both items. The analysis began as the researcher read through the free-response comments while looking for either common ideas between people, or particularly insightful or important thoughts. Next, comments were categorized according to these common ideas and reread for the purpose of identifying additional subcategories. This process was repeated several times. The resulting organization, with the frequency each category or subcategory was mentioned in the comments, is reproduced in Table 9.

Table 9

Categorization of Free-Response Entries with Frequency of Mentions

Category or subcategory	Frequency mentioned
Instructional Content	
Positive responses	3
Content	
Easy to understand	4
Simplified complex material	2
Generally useful	1
Useful for studying for examinations	2
Materials	
Videos	5
Cases	1
Assessments	3
Negative responses	
Lacks hands-on training in skills	1
Lacks tabular organization of material	1
Aesthetics and Design	
Positive responses	
Presentation style	1
Conciseness of material	1
Ability to save work and return	1
Negative responses	
Confusing navigation	17
Lacks a physical component for reference	1
Intervention is too long	1

Note. $n = 25$.

Though the directions for the two free-response items ostensibly divided the comments into different categories, several students made design comments in the content field and vice versa. Whenever this happened, the pertinent response was moved to its most appropriate category or subcategory. Actual user comments are reproduced in Appendix G.

General comments. By far, the most common response was a declamation of the *Moodle*-based intervention's unforgiving navigation, with 17 different participants commenting upon it. The intervention was composed of many learning objects, created and organized in *Moodle*. Participants noted that each element type had its own navigation, making it confusing to work through, and that *Moodle* lacked a method for participants to track their progression through the intervention.

Some ideas were mentioned by multiple participants. Three expressed a generally positive view toward the content. Four participants noted the material was easy to understand. Two felt the intervention made the complex subject of the cranial nerves more accessible. Two others found the material useful as a review for the semester examinations in *Neuroanatomy* course. Five respondents identified the embedded *YouTube* video elements as being particularly helpful, while three mentioned the assessment items helped them learn the content.

Single respondents reported:

- Finding the content generally useful;
- Utility of the case-based presentation of material;
- A need for additional details, organized in tables;
- A need for hands-on practice with the skills presented;

- Appreciation for the presentation style used;
- Appreciation for the conciseness of content;
- Using the ability to save progress across multiple sessions;
- A need for a physical reference component, with some of the content printed on it; and
- A perception that the intervention was too long.

Specific comments. Several responses included comments specific to a particular element of the intervention that are therefore not generalizable to the intervention as a whole. One respondent liked that the embedded *YouTube* videos linked to other helpful videos upon finishing. Another jocularly inquired if similar interventions could be created to replace those from a commercially-published suite of virtual wet-labs that were used in other courses.

Negatively, participants indicated that the fifth question on the pre-/post-test and material explaining a particular clinical test were confusing, that the speaker in an embedded *YouTube* video was difficult to understand, and that the videos did not always work (though the reporter admitted this may have been a problem with his or her personal wireless Internet connection). One respondent reported the malfunction of a *Moodle*-based progress bar element.

Research question 4. The fourth research question reads: "What are the perceptions of first-year optometry students about a self-paced, online cranial nerve intervention after finishing the course that contained the intervention?" To answer this question, the researcher analyzed interview data obtained from eight one-on-one interviews with part II participants. The semi-structured interviews were performed according to the interview protocol instrument (see Appendix F), transcribed using a word processing document (Appendix H), and reviewed by the researcher, who identified ideas and statements in common and at odds between participants. Using a notebook, these ideas were categorized, reviewed, and reclassified (Figures 1 and 2), which allowed the distillation of the six basic lessons of the interview responses. These are:

1) *Understanding the Cranial Nerves* deepened participants' understanding of the cranial nerves, both in their knowledge of academic details and clinical testing;
2) Though preferable to learning complex material from lectures and textbooks, participants preferred a more interactive, audiovisual content presentation to this intervention's text-heavy content with embedded multimedia; Participants liked being led through the material step-by-step at their own paces;
3) The intervention's length was cumbersome and made review for the examinations difficult;
4) It is unclear whether participants perceive an examination performance benefit from the intervention; and
5) Building the intervention on the *Moodle* LMS led to extensive navigation problems.

Additional Analysis

As mentioned above, the Chronbach's *alpha* coefficient for the 13 Likert-style items in the Content and Instruction subscale, and 6 items in the Aesthetics and Design subscale, were low (.148 and 1.50, respectively), which brought into question the internal

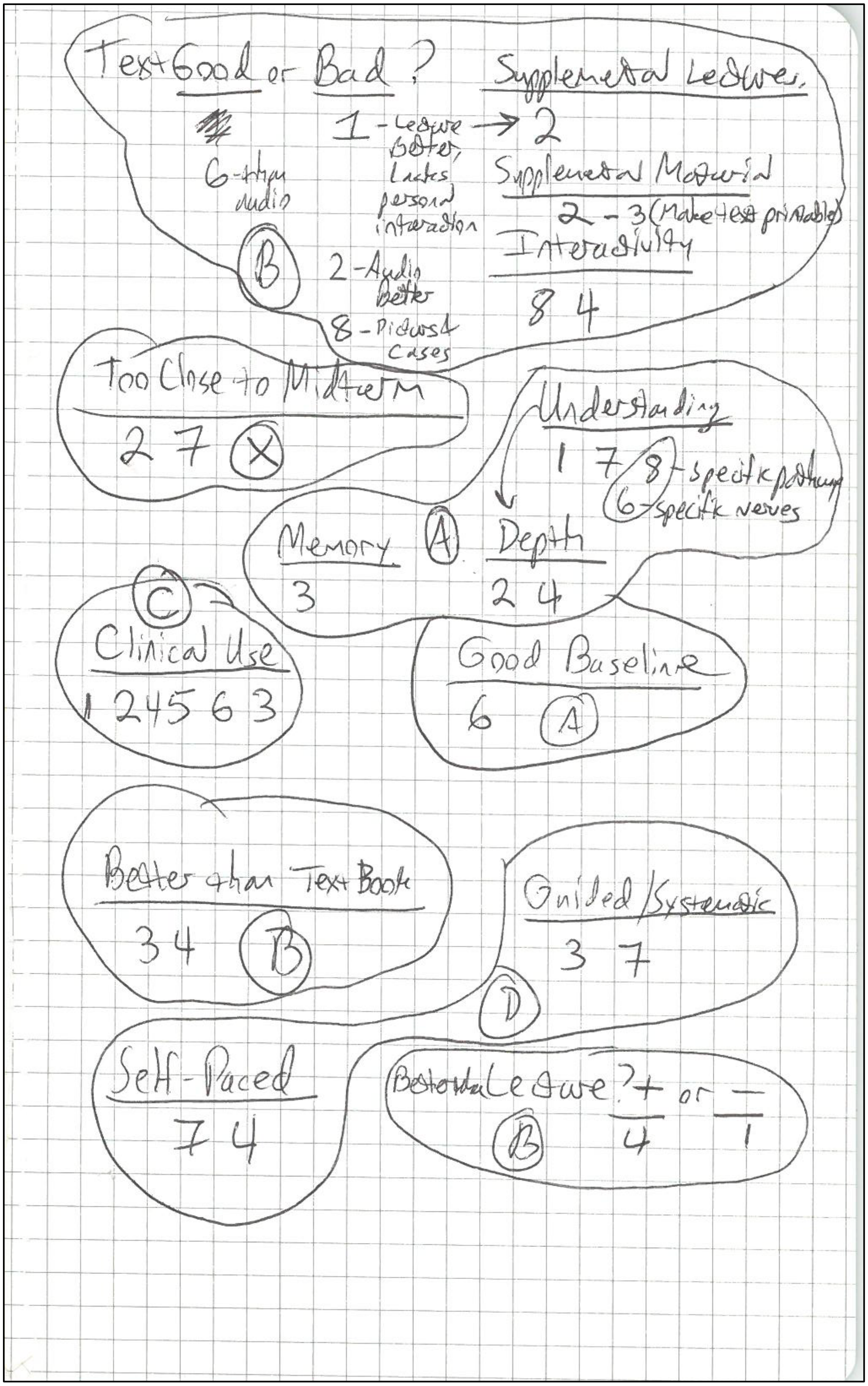

Figure 1. Initial Categorization of Interview Comments.

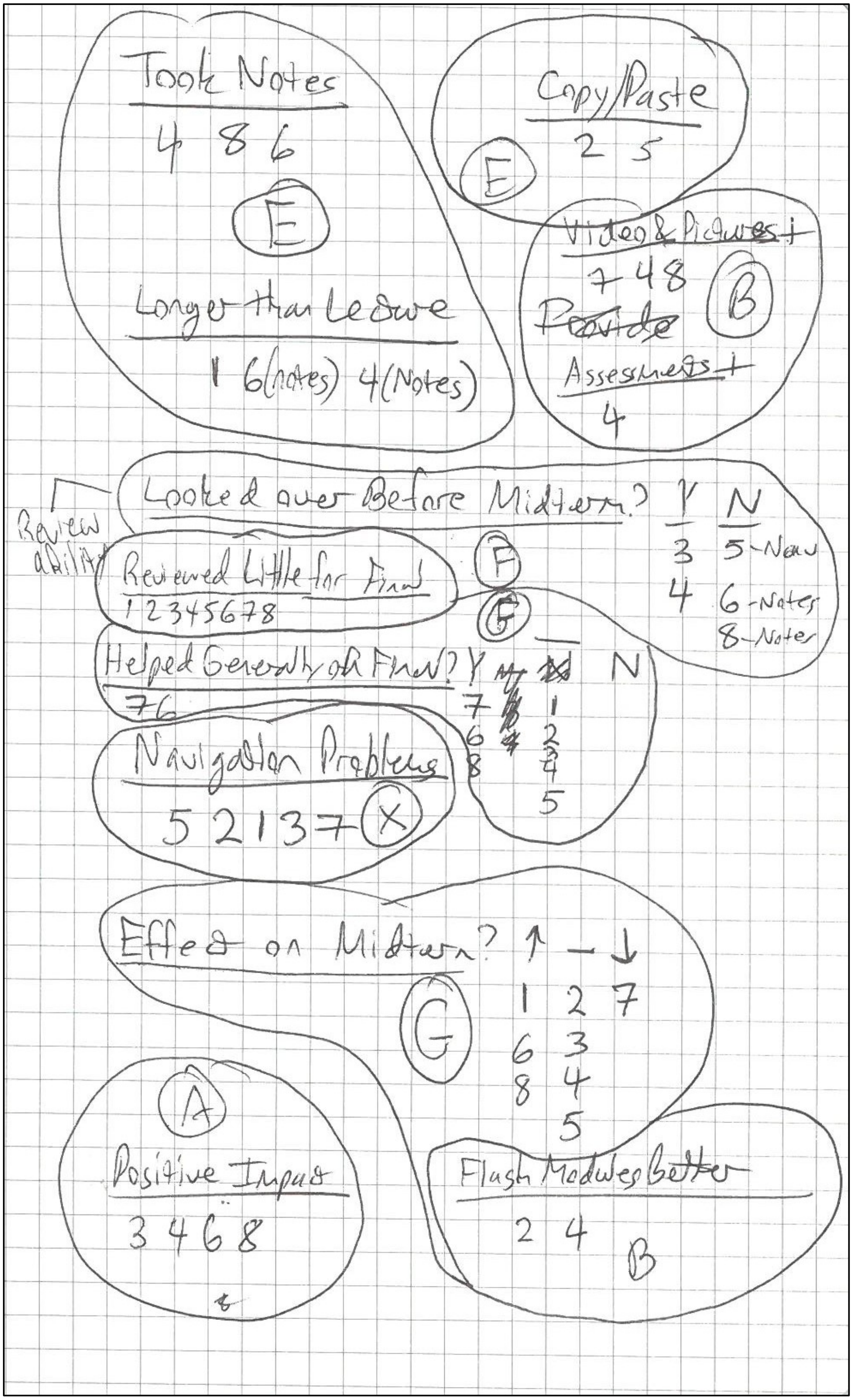

Figure 1, continued.

A. Main Effect – Positive (4)
– Deepens Understanding (4)
– Clarifies Specific Pathways (2)
– Material Depth (2)
– Helps Memory (1)
– Provides Foundation (1)

B. Media Choice – Text:
∘ Better than audio (1)
∘ Worse than lecture (2) ∘ Worse than Flash (2)
∘ Worse than audio (1)
∘ Worse than pictures & cases (1)
Module: ∘ Needs printed supplementation (2)
∘ Better than lecture (1)
∘ Better than textbook (2)
∘ ~~Good~~, due to interactivity (2)
∘ Good, due to ~~the~~ Multimedia (3)
∘ Good, due to assessments (1)

C. Clinically Useful (6)

D. Design Elements – Systematic Organization was good (2)
– Self-paced was good (2)

E. How was it used? – Took Notes (Mentioned; 3)
– Copy/~~Pasted~~ Text (Mentioned; 2)
(*) < – Took longer than 1.75 hours? (2)
– Took longer than lecture? (3)

F. Exam Prep – Midterm: (2) reviewed module
(2) reviewed notes
(1) didn't review module due to Navigation
– Final: (8) didn't review much

G. Exam effect – Midterm 3, 4, (1) – due to false security
– Final 3, 5, 0

X. Technical: (2) Too close to Midterm
(2) Technical Video problems
(5) Navigation/Moodle problems.

Figure 2. Summary of Interview Response Ideas.

consistency reliability between individual items. However, since only 6 participants completed the formative evaluation process from which the data were drawn, it is questionable whether the low *alpha* coefficients were merely results of the small sample size. To test this, the researcher calculated Chronbach's *alpha* coefficient for both subscales using the study results. The Content and Instruction subscale had a Chronbach's *alpha* coefficient of .906, and the Aesthetics and Design subscale had a Chronbach's *alpha* coefficient of .853—both strong results—with $n = 61$ in both cases.

Summary

By following the protocols of Chapter Three, considerable data were obtained for analysis. After defining the data using descriptive statistics, the researcher determined that completion of *Understanding the Cranial Nerves* was quite effective for promotion of factual recall and clinical decision making regarding the cranial nerves.

Using a variety of methods, the researcher determined that student participants held generally positive views of the intervention. As a group, the participants understood the content deeply and found it clinically-useful. The participants also liked the intervention's self-paced nature and its audiovisual components. It was obvious, however, that the *Moodle* LMS-based organization and navigation were not user-friendly, and the content may have been overly reliant on text.

In the final chapter, the implications of these results will be explored according to the foundational materials contained in Chapters 1 and 2, with a focus on practical considerations for permanent implementation, and suggested directions for future research.

Chapter 5: Discussion and Conclusions

In Chapter 4, the research questions were addressed based upon implications drawn from the totality of the gathered data. In this chapter, these answers will be put in context. Specifically, a summary of previous chapters will be followed by a discussion of the relative meaning of the findings and an exploration of possible avenues for research based upon what has been discovered. The chapter will end with a final review of the conclusions that can be drawn from the results of the study.

Summary of the Study

The purposes of this study were to determine the effect of a self-paced, online intervention upon factual recall and clinical thought, and also to understand students' perceptions of such an intervention. The researcher developed these purposes according to his informal understanding of the related perceptions of SCO faculty; specifically, that optometry students enter their clinical assignments having forgotten previously-learned basic science knowledge and lacking in clinical thinking ability. For an interventional subject, the researcher chose a vital component of optometric knowledge, namely a student's clinical understanding and assessment of the cranial nerves.

The cognitive efficacy of the intervention was assessed by comparing student participants' scores on clinically-based pre-tests and post-tests (see Appendix D) and analyzing the change between the two test scores. General factual recall and clinical decision making were both assessed by comparing scores between applicable pre-/post-test items.

To evaluate students' perceptions of the intervention, the following techniques were used: (1) a 21-item Likert-type survey measured specific perceptions of interest immediately after completion of the intervention; (2) two free-response text boxes in the survey allowed participants to give immediate, free-form feedback on the intervention; and (3) an eight-question semi-structured interview protocol elicited comments on the intervention several months after the completion of the *Neuroanatomy* course within which it was presented.

The number of participants was different for each instrument, due to the division of the instruments into two separate phases in the research protocol, and a somewhat inconsistent level of instrument completion among the participants. The cohort of current first-year students at SCO yielded the participant pool, who were self-determined by opting in to the study. Of the 71 first-year students who opted in, 66 completed pre-tests and post-tests (a non-random convenience sample), 61 completed Likert-type survey items (another non-random convenience sample), 25 responded to free-response survey items (a criterion sample), and 8 completed interviews (another criterion sample). Only these participants' results were analyzed. The study included four research questions:

1) To what extent does completion of a self-paced, online cranial nerve intervention improve factual recall among first-year optometry students?
2) To what extent does completion of a self-paced, online cranial nerve intervention improve clinical thinking ability among first-year optometry students?
3) What are the perceptions of first-year optometry students about a self-paced, online cranial nerve intervention immediately after completing it?
4) What are the perceptions of first-year optometry students about a self-paced, online cranial nerve intervention after finishing the course that contained the

intervention?

For the first two research questions, one-tailed, one-sample Student's *t*-tests were performed, with Cohen's *d* effect sizes calculated for significant results. These quantitative tests compared the participant group's mean change between the pre-test and post-test to no change at all, and the group's mean change on pre-/post-test clinical thinking items to no change. These results assessed whether factual recall and clinical decision making improved as a result of the intervention.

The variety of data gleaned for understanding of the third and fourth research questions required several analysis methods. Free-response and interview data were reviewed by the researcher numerous times to determine common and unique ideas of interest. Likert-type data was quantitatively analyzed for goodness-of-fit to an expected frequency distribution via the Pearson *chi*-squared test. The totality of these results together provided the answers to research questions three and four.

Discussion of the Findings

The results of the statistical and review processes are presented in Chapter 4. The following discussion describes and explains the meaning of these results.

Research question 1. The first research question reads: "To what extent does completion of a self-paced, online cranial nerve intervention improve factual recall among first-year optometry students?" The items on the pre-/post-test (and for that matter, all the instructional content of the intervention) were designed around the eight learning objectives of the *Understanding the Cranial Nerves* module (see Table 2). Since learners would be able to answer the questions without knowledge of the interventional content, it can be said that all pre-/post-test items measure factual recall, though some may measure other cognitive skills also. For example, items 3, 5, 6, and 7 (see Appendix D) all require the learner to reason through the possible diagnoses to determine the best answer, although even these higher-order thought processes are founded upon previously-learned facts (Faucher, 2011). Though the intervention was designed to require critical thinking, the study's lack of standardized pre-/post-test items, the short duration of the intervention, and absence of a control group restricts analysis of the extent to which critical thinking was actually learned (Behar-Horenstein & Niu, 2011; Facione, 1990; Niu et al., 2013; Lai, 2011; Tiruneh et al., 2014; Yuan et al., 2008).

The improvement in factual recall from the pre-test to the post-test was statistically-significant via Student's *t*-test, with a large effect size that indicates a strong learning effect. However, the lack of an equivalent control group does not allow any evidence-based comparative statement to be made between the factual recall efficacy of a self-paced, online intervention like *Understanding the Cranial Nerves* and other content presentation methods.

As Rae and Samuels (2011) demonstrated, a LMS-based, multimedia, interactive self-paced course, designed around the tenets of PSI was effective for teaching cognitive skills. Though such a model has similarities with *Understanding the Cranial Nerves*, the intervention can hardly be defined as a PSI course. Though it is self-paced, and presents most of its content through text and text corollaries, the embedded quizzes only test conversance, not mastery. It also lacks reward lectures and the personal interaction of peer tutors. Fortunately, its inadequacies may be minimized by its strong learner-content interaction, a powerful concept in equivalency theorum (Rhode, 2009).

Research question 2. The second research question was: "To what extent does completion of a self-paced, online cranial nerve intervention improve clinical thinking ability among first-year optometry students?" The protocol for this research question was similar to that of the first, although only those pre-/post-test items that require clinical decision making were considered under this question. Thus, the items that have direct clinical implications beyond mere memorization and recall—those that require clinical thinking as defined by Faucher (2011)—are separated from the others. The same concerns apply here as in research question one: the lack of both standardized pre-/post-test items and a control group lead to an inability to perform evidence-based comparisons against traditional teaching methods. However, the strength of the results (measured by effect size) may informally mitigate the previously-discussed perception among the optometry school faculty that students lack a clinically-relevant understanding of the cranial nerves (Taylor, 2015).

The fact that the instruction and pre-/post-test items are clinically oriented fulfills one of Drake and Pawlina's (2013) four key requirements of multimodiality theory. The other requirements were not similarly observed: apart from manipulating the mouse, there is no kinesthetic-based learning; since active learning is almost entirely team-based, the intervention lacks any such component; and long-term reinforcement of the material must necessarily occur outside the semester-long duration of the *Neuroanatomy* course. While kinesthetic and active-learning techniques could be introduced in a complementary classroom-based intervention, it is difficult to see how long-term reinforcement (beyond the length of a semester) could be added without major changes to either the *Neuroanatomy* course or overall curriculum at SCO. It is worth noting that some long-term reinforcement will occur informally as the participants see patients in the clinic and study for their national board examinations as third-year students.

Research questions 3 and 4. The third research question reads: “What are the perceptions of first-year optometry students about a self-paced, online cranial nerve intervention immediately after completing it?” The fourth research question reads: “What are the perceptions of first-year optometry students about a self-paced, online cranial nerve intervention after finishing the course that contained the intervention?” Though more specific, participants’ perceptions immediately after completing the intervention were generally similar to those obtained several months afterwards. Both quantitatively-measured and free-response perceptions were broadly positive, with emphases on the depth of understanding presented in *Understanding the Cranial Nerves* and its engaging design.

The apparent tendency of participants to select the highest two options in the Likert-type ordinal scales may have skewed those items downward, making it more difficult for superlative features to emerge statistically from the generally high item scores. This at least made it easier to spot problem areas (like navigation difficulties with the *Moodle* interface) using this instrument.

Participants’ appreciation for both the embedded video and interactive quizzes supports Southard et al.’s (2015) contention that effective online education should possess rich, dynamic instruction, high-impact production elements, and interactive content. Interestingly, one concern—reported by several respondents—was that different elements of the intervention were not uniform in their navigation and presentation. This suggests a failure in the fourth component of effective online education: consistent structure. To the extent it was missing in *Understanding the Cranial Nerves*, participants noticed.

Implications for Practice

The study suggests that self-paced, online, clinically-based education like *Understanding the Cranial Nerves* can be useful in optometric education, for both teaching important facts and practicing clinical decision making skills, though its generalizability to other subjects is merely assumed. Its lack of a control group and nature as a single case study should give the prudent reader pause. The implementation of similar modular programs is best performed with patience and caution, by adding such elements to an existing course slowly and taking time to evaluate their effects before expanding the method to other subjects. Should positive results continue to be demonstrated with this and similar interventions, it would support more extensive curricular changes.

Teachers in optometric education, the health professions, and those teaching cranial nerve assessment should consider following the best-practices of Southard et al. (2015) and Rhode (2009) when developing online, self-paced educational elements. The intentional construction of rich instructional content, high-impact multimedia elements, interactivity, and strong learner-content relationships are likely to help improve student perceptions of such modules. The importance of hosting such interventions on a thoroughly debugged software platform is an obvious necessity that becomes an even more pronounced problem if ignored.

According to Drake and Pawlina (2013), instructional interventions for health care topics should be designed to take full advantage of the multimodal capabilities of the Internet. Specifically, interested designers should organize content around clinical scenarios, encourage active-learning (perhaps using message boards and online chat sessions), and develop kinesthetic techniques to support knowledge transfer and recall.

Recommendations for Future Research

As already stated, the most obvious drawbacks of this study are its lack of a control group and short duration. A true treatment/control study lasting longer than one academic semester (15 weeks) would increase the generalizability of the study to similar situations and subjects, and would be a welcome addition to the literature (Behar-Horenstein & Niu, 2011; Facione, 1990; Niu et al., 2013; Lai, 2011; Tiruneh et al., 2014; Yuan et al., 2008). In the event that such adjustments remain logistically impossible, the treatment group could be compared against controls drawn retrospectively from previous, lecture-based iterations of the *Neuroanatomy* course. As in Taylor (2015), one could determine Pearson product-moment (*r*) correlations between examination score and the percentage of cranial nerve-related items on those examinations. *r* coefficients from the control group could be compared to those of the treatment group via a two-sample Student's *t*-test to determine whether a significant improvement in educational outcomes exists. Though this second research approach would contain some major concerns (such as the assumption of equivalence between different cohorts), it could elicit some interesting and useful information.

The need for an intervention like *Understanding the Cranial Nerves* was based upon a common perception among the SCO faculty that optometry students' factual knowledge base is often inadequate for the rigors of third-year clinic. Thus, it would be interesting to study whether third-year students who completed *Understanding the Cranial Nerves* were better prepared than their predecessors. Since the variable here is preparedness, one hesitates to suggest the use of a knowledge examination for assessment. Rather, a survey or series of interviews of faculty members could help determine whether students seem more prepared, though the intervention's short duration makes such an outcome somewhat doubtful.

The concept of self-regulated learning (SRL) was not discussed in this study apart from its description in Chapter 2. Regardless, it presents intriguing possibilities for the improvement of learning outcomes in online modules. It would be interesting to build a similar intervention to *Understanding the Cranial Nerves*, but with added elements that encourage self-regulation, such as mandated and scheduled learner-instructor interactions, system-generated feedback based on learners' responses to an assessment, and including instruction on how to use the LMS. The achievement of learning outcomes from the SRL-designed module could be compared to that of a non-SRL-designed module, like the original *Understanding the Cranial Nerves* (Cho & Heron, 2015).

Conclusion

This study found that a carefully designed, clinically-based, self-paced, online module had a significant positive effect on factual recall of cranial nerve and cranial nerve assessment details, and on clinical decision making ability. First-year optometry students taking such an intervention tended to find the experience enjoyable and helpful for their professional educational goals, both immediately after completing the two-hour intervention, and in the following months.

Those involved in optometric and health professions education, or any context in which detailed, medically-based information is being taught for practical purposes, should consider developing and using such modules to supplement existing course materials. Those taking such a step would be well advised to consult the extensive design literature, so as to increase the robustness and efficacy of their instruction. Specifically, Southard et al. (2015) and Rhode's (2009) recommendations for creation of robust online content, and Drake and Pawlina's (2013) guidelines for incorporating multimodiality theory in online education would help drive the interested educator down a sure road of instructional design.

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Appendix A: Used Keyword List

- Multimodiality
- Multimodiality theory
- Gross anatomy education
- Cranial nerves education
- Cranial nerve assessment education
- Cranial nerves online
- Optometric cranial nerves education
- Self-paced education
- Keller plan
- Personalized System of Instruction
- CAPSI
- Computer-assisted Personalized System of Instruction
- Self-paced online education
- Optometric online education
- Critical thinking
- Clinical thinking
- Optometric critical thinking
- Critical thinking in cranial nerves

Appendix B: Recruitment Letters

Part I Recruitment Letter

Southern College of Optometry/The University of Memphis

Volunteers Wanted for a Research Study

Dr. Daniel Taylor, under the direction of Dr. Trey Martindale at the University of Memphis, is studying the effectiveness of the online module, *Understanding the Cranial Nerves*, in the context of the OPT 113 class. As part of this, he would like to use data from your responses to this module. The data will be statistically analyzed and qualitatively studied for patterns, when appropriate.

Should you agree to participate in the study, your data will be depersonalized to protect your identity.

Benefits of the study include an opportunity to help make this module better for continued use.

There is no compensation promised or implied for participant or completion of this study. There is no penalty for refusing to participate in the research study portion of this module.

Should you choose not to participate in the study, you still must complete *Understanding the Cranial Nerves* as part of your Neuroanatomy class. Your personal data will not be used in the study, however.

Click here to read the informed consent document for this study.

For information about this research, contact Dr. Daniel Taylor via email at dtaylor@sco.edu.

This research is conducted under the direction of Dr. Trey Martindale, The

University of Memphis, Instruction and Curricular Design, who can be contacted at emartndl@memphis.edu.

Part II Recruitment Letter

Southern College of Optometry/The University of Memphis

Volunteers Wanted for a Research Study

Dr. Daniel Taylor is studying the effectiveness of the online module, *Understanding the Cranial Nerves*, in the context of the OPT 113 class. As part of this, he would like to interview first-year students who have completed the module and OPT 113 class. These interviews will be one-to-one and be based upon a predetermined script of questions. Participants can expect an interview to take approximately 30 minutes to an hour.

Only the first eight respondents will be selected to participate in this research project, assuming no scheduling problems.

Benefits of the study include an opportunity to express your thoughts about *Understanding the Cranial Nerves* and potentially be involved in improving the module for future students.

There will be no compensation promised or implied for completion of this study.

For information about this research, contact Dr. Daniel Taylor via email at dtaylor@sco.edu.

This research is conducted under the direction of Dr. Trey Martindale, The University of Memphis, Instruction and Curricular Design, who can be contacted at emartndl@memphis.edu.

Appendix C: Informed Consent Forms

Consent to Participate in a Research Study

Evaluation of *Understanding the Cranial Nerves, Part 1*

WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?

You are being invited to take part in a research study about the Internet-based module, *Understanding the Cranial Nerves* (hereafter, "*the module*"). You are being invited to take part in this research study because you are an active student in the Neuroanatomy (hereafter, "*OPT 113*") course. If you volunteer to take part in this study, you will be one of about one hundred thirty-six people to do so.

WHO IS DOING THE STUDY?

The person in charge of this study is Daniel A. Taylor (hereafter, "*lead investigator*") of the University of Memphis Department of Education. He is being guided in this research by Trey Martindale of the University of Memphis Department of Education. There may be other people on the research team assisting at different times during the study.

WHAT IS THE PURPOSE OF THIS STUDY?

By doing this study, we hope to learn the impact that the module has upon first-year students' experience in OPT 113. We are particularly interested in your impressions of its impact on particular elements of the experience, the information you learned from the module, and its overall usefulness or lack thereof.

ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?

If you are not enrolled in OPT 113, you should not take part in this study.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT

LAST?

The research procedures will be conducted at online as you complete *Understanding the Cranial Nerves*. You will need to log in to the Southern College of Optometry Moodle page at least once and complete the *Understanding the Cranial Nerves* module. This will take about 120 minutes. The total amount of time you will be asked to volunteer for this study is 120 minutes over the next month.

WHAT WILL YOU BE ASKED TO DO?

You will be asked a series of knowledge and survey questions by the module. These questions have been scripted prior to your participation in the study, and will be related to your understanding of cranial nerves, and the impact the module had on your experience in OPT 113. Your responses will be recorded for future analysis.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life.

You may find some questions we ask you to be upsetting or stressful. If so, we can tell you about some people who may be able to help you with these feelings.

In addition to the risks listed above, you may experience a previously unknown risk or side effect.

WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?

You will not get any personal benefit from taking part in this study.

DO YOU HAVE TO TAKE PART IN THE STUDY?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. As a student, if you decide not to take part in this study, your choice will have no effect on your academic status or grade in the class.

IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?

If you do not want to be in the study, there are no other choices except not to take part in the study.

WHAT WILL IT COST YOU TO PARTICIPATE?

There are no costs associated with taking part in the study.

WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?

You will not receive any rewards or payment for taking part in the study.

WHO WILL SEE THE INFORMATION THAT YOU GIVE?

We will make every effort to keep private all research records that identify you to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be personally identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. Your name will not be referenced in personal conversation or written communication. Your responses to online forms will be stored in a password-protected file on the lead instructor's hard drive. Any analysis of this recording will use a random participant number to refer to you.

We will keep private all research records that identify you to the extent allowed by law. However, there are some circumstances in which we may have to show your information to other people. For example, the law may require us to show your information to a court or to tell authorities if you report information about a child being abused or if you pose a danger to yourself or someone else. Also, we may be required to show information which identifies you to people who need to be sure we have done the research correctly; these would be people from such organizations as the University of Memphis and Southern College of Optometry.

CAN YOUR TAKING PART IN THE STUDY END EARLY?

If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in the study.

The individuals conducting the study may need to withdraw you from the study. This may occur if you are not able to follow the directions they give you, if they find that your being in the study is more risk than benefit to you, or if the agency funding the study decides to stop the study early for a variety of scientific reasons.

To withdraw, simply inform the lead evaluator at any time that you do not wish to continue via email. You will still need to complete the module questions as part of your coursework, but your results will not be used in any research.

WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR

COMPLAINTS?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Daniel A. Taylor, at 901-722-3246 or via email at dtaylor@sco.edu, or his dissertation advisor, Trey Martindale, at emartndl@memphis.edu. If you have any questions about your rights as a volunteer in this research, contact the Institutional Review Board staff at the University of Memphis at 901-678-2705. We will give you a signed copy of this consent form to take with you.

WHAT HAPPENS TO MY PRIVACY IF I PARTICIPATE?

A random ID number will be assigned to you to prevent confidentiality violations when the lead evaluator analyzes and reports the results. Participants will complete the response portions of the research in the SCO Moodle web portal, which will record their module responses according to student ID number and name (as per the setup at SCO). Results will be identified by propagating a report from Moodle, in which student ID numbers, pre-test results, post-test results, and survey results are reported for all participants who agreed to have their data analyzed. Each participant will receive a randomly-assigned study number, as created from random.org. The study numbers will be sorted against SCO student ID numbers in a reference file on the LI's computer, which will be password protected. The Moodle results report from this portion will have study numbers added and student ID numbers deleted to protect privacy.

WHAT ELSE DO YOU NEED TO KNOW?

There are no organizations involved in this study, financially or otherwise, other than the University of Memphis and Southern College of Optometry.

To agree to the study, assert that you wish to participate on the Assent page and type your name in the text box as an e-signature.

You may save this document for your reference.

Consent to Participate in a Research Study

Evaluation of Understanding the Cranial Nerves, Part 2

WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?

You are being invited to take part in a research study about the Internet-based module, Understanding the Cranial Nerves (hereafter, “the module”). You are being invited to take part in this research study because you have successfully completed the module and the Neuroanatomy (hereafter, “OPT 113”) course. You also completed part 1 of the research by assenting to allow your results from Understanding the Cranial Nerves to be used in research. If you volunteer to take part in this study, you will be one of about eight people to do so.

WHO IS DOING THE STUDY?

The person in charge of this study is Daniel A. Taylor (hereafter, “lead investigator”) of the University of Memphis Department of Education. He is being guided in this research by Trey Martindale of the University of Memphis Department of Education. There may be other people on the research team assisting at different times during the study.

WHAT IS THE PURPOSE OF THIS STUDY?

By doing this study, we hope to learn the impact that the module has upon first-year students’ experience in OPT 113. We are particularly interested in your impressions of its impact on particular elements of the experience, and its overall usefulness or lack thereof.

ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?

If you did not complete *Understanding the Cranial Nerves*, assent to the research in that module, or complete OPT 113 with a passing grade, you should not take part in this study.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?

The research procedures will be conducted at Southern College of Optometry. You will need to come to Tower 129 one time during the study. This visit will take about 30 minutes. The total amount of time you will be asked to volunteer for this study is 30 minutes over the next month.

WHAT WILL YOU BE ASKED TO DO?

You will be asked a series of experimental interview questions by the lead investigator. These questions have been scripted prior to your participation in the study, and will be related to the impact the module had on your experience in OPT 113. Your responses will be recorded for future analysis.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life.

You may find some questions we ask you to be upsetting or stressful. If so, we can tell you about some people who may be able to help you with these feelings.

In addition to the risks listed above, you may experience a previously unknown risk or side effect.

WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?

You will not get any personal benefit from taking part in this study.

DO YOU HAVE TO TAKE PART IN THE STUDY?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. As a student, if you decide not to take part in this study, your choice will have no effect on your academic status or grade in the class.

IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?

If you do not want to be in the study, there are no other choices except not to take part in the study.

WHAT WILL IT COST YOU TO PARTICIPATE?

There are no costs associated with taking part in the study.

WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?

You will not receive any rewards or payment for taking part in the study.

WHO WILL SEE THE INFORMATION THAT YOU GIVE?

We will make every effort to keep private all research records that identify you to the extent allowed by law.

Your information will be combined with information from other people taking part in the study. When we write about the study to share it with other researchers, we will write about the combined information we have gathered. You will not be personally identified in these written materials. We may publish the results of this study; however, we will keep your name and other identifying information private.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. Your name will not be referenced in personal conversation or written communication. Your recorded interview will be stored in a password-protected file on the lead instructor's hard drive. Any analysis of this recording will use a random participant number to refer to you.

We will keep private all research records that identify you to the extent allowed by law. However, there are some circumstances in which we may have to show your information to other people. For example, the law may require us to show your information to a court or to tell authorities if you report information about a child being abused or if you pose a danger to yourself or someone else. Also, we may be required to show information which identifies you to people who need to be sure we have done the research correctly; these would be people from such organizations as the University of Memphis and Southern College of Optometry.

CAN YOUR TAKING PART IN THE STUDY END EARLY?

If you decide to take part in the study you still have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in the study.

The individuals conducting the study may need to withdraw you from the study. This may occur if you are not able to follow the directions they give you, if they find that your being in the study is more risk than benefit to you, or if the agency funding the study decides to stop the study early for a variety of scientific reasons.

To withdraw, simply inform the lead evaluator at any time that you do not wish to continue.

WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR

COMPLAINTS?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Daniel A. Taylor, at 901-722-3246 or via email at dtaylor@sco.edu, or his dissertation advisor, Trey Martindale at emartndl@memphis.edu. If you have any questions about your rights as a volunteer in this research, contact the Institutional Review Board staff at the University of Memphis at 901-678-2705. We will give you a signed copy of this consent form to take with you.

WHAT HAPPENS TO MY PRIVACY IF I AM INTERVIEWED?

The first eight volunteers who return a signed informed consent will be contacted via email to schedule a time for an interview. Upon successful scheduling, the password-protected reference file from part 1 of the study will be opened, and your study numbers will be identified based upon your student ID number. From this point, in all interview recordings, documentation, and communications, you will be referred to by your study number only.

WHAT ELSE DO YOU NEED TO KNOW?

There are no organizations involved in this study, financially or otherwise, other than the University of Memphis and Southern College of Optometry.

____ ____________

Signature of person agreeing to take part in the study Date

____

Printed name of person agreeing to take part in the study

____ _____________

Name of [authorized] person obtaining informed consent Date

Appendix D: Pre-Test/Post-Test Script with Answers

Directions: Over the following pages, you will have eight questions to answer about cranial nerves and their clinical implications. Follow the directions in each item and answer to the best of your ability.

Underlined text are the answers, and do not appear in the actual pre-/post-tests.

Item #1: Select the rule that is useful when clinically assessing cranial nerves and their implications.

A. Multiple neurological symptoms imply central nervous system involvement

B. Eye movement information gives little information about the cavernous sinus

C. Olfactory testing is most important when assessing headaches

Item #2: Look at this list of clinical symptoms. Identify *all* the symptoms that likely have neurological implications.

A. Headaches

B. Sharp transient ocular pain

C. Dry mouth after running

D. The left side of the mouth drooping more than the right

E. Blurry vision without glasses

F. Constant, rhythmic eye movements of recent onset

G. Stuffy nose

H. <u>Loss of sensation around the eye</u>

I. <u>Dizziness</u>

Item #3: A forty-two year old white female complains of double vision for two months. It has been more or less constant over that time, but since then she has also noticed difficulty hearing quiet sounds on the right side, and has had intermittent trouble swallowing.

Which of these conditions *best* accounts for this history?

A. Myasthenia gravis

B. Brainstem stroke

C. <u>Increased intracranial pressure</u>

D. Diabetic neuropathy

Item #4: Arrange this list of cranial nerves in the order you would perform cranial nerve testing in the optometric clinic. <u>Listed order is correct.</u>

- Cranial Nerve II
- Cranial Nerves II, IV, and VI
- Cranial Nerve I
- Cranial Nerve VIII
- Cranial Nerve V
- Cranial Nerves IX and X
- Cranial Nerve XII
- Cranial Nerve VII

- Cranial Nerve XI

Item #5: On pupil testing, your patient's right pupil constricts on direct testing, but the left pupil remains dilated. During your swinging flashlight test, neither pupil moves. Which is the most likely reason for this presentation?

A. <u>The left pupil is pharmacologically dilated</u>
B. The left optic nerve is injured
C. The left oculomotor nerve is injured
D. The right optic nerve is injured

Item #6: While testing extraocular muscle movement on a 70-year old black male with diabetes mellitus, you notice that the right eye habitually positions downwardly and to the right. Select the test you should run next, and why.

A. Pupil testing, to determine the health of CN II
B. Facial sensitivity testing, to assure there is no aberrant regeneration
C. Tongue protrusion testing, to determine if taste has been affected
D. <u>Pupil testing, to determine if there is pupil involvement</u>

Item #7: You perform facial nerve testing on your patient. His forehead is equally wrinkled on both sides, and his eyelids are equally resistant to forced opening. However, upon attempting to bare his teeth, the right side of his mouth fails to do so.
At this point, which of these diagnoses seems most likely?

A. Right upper motor neuron palsy of the facial pathway

B. <u>Left upper motor neuron palsy of the facial pathway</u>

C. Right lower motor neuron palsy of the facial nerve

D. Left lower motor neuron palsy of the facial nerve

Item #8: Your patient complains of severe headaches waking her from sleep three times in the past week. You wisely decide to perform cranial nerve testing in addition to your normal eye examination. You obtain the following results:

- VAsc (6m): 20/20 OD, OS, OU
- Cover Test 6m: Orthophoria
- Confrontation Fields: FTFC OU
- EOMs: FROM OU (-)pain (-)diplopia
- Pupils: PERRLA (-)RAPD
- Refraction: Plano DS OD, OS, OU
- Odoriferous stimuli test: R&L equal with cinnamon and lemon rind
- Rubbing fingers test: R&L equal
- Facial sensation test: 6/6, sharp and soft
- Uvula centered, R&L gag reflex present
- Tongue protrusion: tongue protrudes to the left
- Eye closure against resistance: R&L equal
- Teeth baring: R&L equal
- Head turn and shoulder shrug: R&L equal
- Ocular health evaluation: Unremarkable
- Goldman Applanation Tonometry: 14 OD, 13 OS @ 3:15 PM

From List One, select the abnormal finding. From List Two, select its implication.

List One	**List Two**
Rubbing fingers test: R&L equal	Right CN II insult
Tongue protrusion: tongue protrudes to the left	Right CN X insult
Pupils: PERRLA (-)RAPD	Left CN VII lower-motor neuron insult
Facial sensation test: 6/6, sharp and soft	Bilaterial CN III insult
Head turn and shoulder shrug: R&L equal	Left CN V_2 insult
Uvula centered, R&L gag reflex present	Left CN XII insult
Odoriferous stimuli test: R&L equal with cinnamon and lemon rind	Right CN IV insult
EOMs: FROM OU (-)pain (-)diplopia	Right CN XI insult
Goldman Applanation Tonometry: 14 OD, 13 OS @ 3:15 PM	Left CN IX insult

Appendix E: Attitude Survey

Attitude Survey

1 * For the following statements, please respond on the following scale, on which 1="Strongly Disagree" and 5="Strongly Agree."

If you have specific comments, type them into the text field at the end of the survey.

	1	2	3	4	5
The content was easy to read and understand.					
The embedded media were easy to follow and helpful.					
In your opinion, the content is applicable to clinical practice.					
In your opinion, the content is applicable to critical thinking.					
All pertinent information was covered in the module.					
Sufficient information was provided to meet the learning objectives.					
The content was helpful in understanding the scientific background behind cranial nerve organization.					
The content was helpful in understanding the scientific background behind cranial nerve assessment.					
The content was helpful in understanding the scientific background behind cranial nerve treatment.					
The content was helpful in understanding how to perform basic cranial nerve testing in the optometric clinic.					
The instruction would be useful if presented in OPT 113 (Neuroanatomy) course.					
The instruction would be useful if presented during clinical practice.					
My courses at SCO adequately prepared me to understand the course material.					

2 Please enter any specific feedback about the instruction here.

Page 1 of 2

Figure 3. Attitude survey instrument from *Understanding the Cranial Nerves*.

Attitude Survey

3 * For the following statements, please answer on the included 1-5 scale, where 1="Strongly Disagree" and 5="Strongly Agree."

	1	2	3	4	5
The overall design of the instruction was attractive.	○	○	○	○	○
The layout of the elements (e.g.: menu bar, content frame) was useful.	○	○	○	○	○
The instruction design maximized ease-of-use.	○	○	○	○	○
The color scheme was attractive.	○	○	○	○	○
The graphics were attractive.	○	○	○	○	○
The text was readable.	○	○	○	○	○

4 * Please enter any specific feedback about the course design here.

Page 2 of 2

Figure 3, continued.

Appendix F: Interview Protocol

Interview Protocol

Name of Interviewer___________________________________ Participant Code ____

Date____________________ Start Time_______________ Finish Time_______________

Instructions to interviewer:

After an individual has signed and returned the informed consent document, read the following script.

> Thank you for agreeing to participate in this evaluation of a new instructional module over the cranial nerves. Now that you have completed the course it was a part of, your thoughts will help update the instruction to make it more useful for future use.

Please be candid and, if needed, brutally-honest as you answer.

Then, begin asking the following questions. For each, record responses, and explore both strengths and weaknesses. Ask additional questions if necessary to elicit an appropriate statement of the participants' thoughts.

Attitude Questions	
How did *Understanding the Cranial Nerves* impact your initial studies of the cranial nerves?	

How did *Understanding the Cranial Nerves* impact your preparations for the second midterm examination in OPT 113?	
How did *Understanding the Cranial Nerves* impact your performance on the second midterm examination in OPT 113?	

How did *Understanding the Cranial Nerves* impact your preparations for the final examination in OPT 113?	
How did *Understanding the Cranial Nerves* impact your performance on the final examination in OPT 113?	

What impact did *Understanding the Cranial Nerves* have upon your overall experience in OPT 113?	
In what ways was *Understanding the Cranial Nerves* most useful?	

In what ways was *Understanding the Cranial Nerves* least useful; or how could *Understanding the Cranial Nerves* be improved?	

Appendix G: Attitude Survey Free Responses Arranged by Idea

Instructional Content

Positive responses.

1) "[T]he sections themselves were very interesting…"

2) "This was great...thank you!"

3) "Material was great…"

Content.

Easy to understand.

1) "I think the information was…easy to understand."

2) "The information was interesting and explained well."

3) "This was so helpful in understanding the cranial nerves."

4) "The content itself was very easy to understand."

Simplified complex material.

1) "I needed this module to simplify this very complex system."

2) "It…definitely helped me solidify my understanding of cranial nerves and their pathways…"

Generally useful.

1) "Mostly useful information…"

Useful for studying for examinations.

1) "[G]reat for studying for exams…"

2) "This was very helpful in understanding the cranial nerves for the next midterm. Thanks!"

Materials.

Videos.

1) "It was nice to watch the testing procedures in the videos."
2) "The videos were helpful…"
3) "The pictures and videos were great!"
4) "The videos were great…"
5) "The video about the upper and lower motor neurons was helpful…"

Cases.

1) "The case studies mimic an actual patient presenting with possible neurological implications, which places us in our future roles as clinicians."

Assessments.

1) "[T]he self-assessments were very useful."
2) "[V]ery applicable quiz questions for each module and the final assessment."
3) "I loved…the quiz format."

Negative responses.

Lacks hands-on training in skills.

1) "Would be great to practice these techniques for one of our lab classes."

Lacks tabular organization of material.

1) "Additional charts of neurological symptoms with correlating diseases or testing would also be a helpful resource for the class."

Aesthetics and Design

Positive responses.

Presentation style.

1) "I felt that the presentation style was extremely beneficial."

Conciseness of material.

1) "I think the information was presented in a concise manner…"

Ability to save work and return.

1) "I…appreciate[d] being able to leave and come back and pick up where I left off."

Negative responses.

Confusing navigation.

1) "It would be nice to complete the entire module in one window, but it is not essential."
2) "Navigating back and forth through sections of the module was awkward and tedious… the layout was slightly annoying to work around."
3) "Navagation [sic] was slightly confusing"
4) "The module was confusing at first because it does not keep track of your progress. I would do sections without knowing it and then accidentally re-do them. It would have been easier to complete if…you could only view the section you clicked on. Sometimes I would click on a section and it would let me go through several without telling me which ones I had completed. It was harder to figure out how to work the module than it was to learn the information."

5) “The module format was a bit difficult to follow to ensure all learning objectives and quizzes were completed.”

6) “The module was a little difficult to follow. If the checklist had worked, it probably would have helped. Also, I think some of the links in the beginning may have been linked incorrectly, because it would repeat the same page.”

7) “The navigation was confusing at first.”

8) “I thought the organization on Moodle was difficult to follow for whether or not I had completed everything in a proper order...Moodle is a little difficult to organize this in.”

9) “Navigation between things isn't the most simplistic. It would be better if it went to one page specifically for the CN module instead of going back to the main course page every time.”

10) “Kept losing my place on Moodle…”

11) “I didn't like having to constantly go back to the course page to proceed to the next portion. Would've been nice to have everything inclusive.”

12) “I found it hard to follow and navigate…particularly to the quizzes. Moodle did not go directly to them after I finished a lesson. I didn't catch that I missed them until I was almost done with the whole assignment and I went into "Grades" and saw I did not receive a grade.”

13) “I had to go back to the OPT 113 home page several times and see where I left off in order to continue down the line of tasks”

14) “It was a little difficult to navigate from the modules to the quizzes to the next module. After the quizzes, Moodle kicks you back to the course page and it is

easy to lose track of the next topic you're supposed to do."

15) "Sometimes one could navigate between sections easily while other times one had to go back to the main page. The buttons location for going back to the main page or continuing was also the same as the ""reattempt quiz"" button, which became quite frustrating. It was very confusing to try and decide which part of the module was just completed."

16) "The module was difficult to navigate because you had to keep leaving the course and opening new windows. It would have been easier to use if it was one continuous module."

17) "Wish I didn't have to back out after each section and scroll back down to the bottom of the page to continue."

Lacks a physical component for reference.

1) "It would have been nice to have a printout, PDF, or worksheet given to us before we began, to follow along with and keep all of the information handy."

Intervention is too long.

1) "Very long."

Specific comments not otherwise classifiable

1) "I thought the wording on the swinging flashlight question on the final assessment was a bit confusing."
2) "The post quiz question five I thought was worded oddly."
3) "The video about the upper and lower motor neurons was helpful, but it was difficult to understand the speaker's accent."

4) “Can we please have more of these instead of PHILS?[1] :) [sic]”
5) “Some of the videos didn't work (but my internet was going in and out while I was doing the module, so it is possible that was the cause).”
6) “The videos…suggested/linked to other helpful videos.”
7) “The percentage of completion bar at the top of the checklist did not work.”

[1] *Ph.ILS* 4.0 is a series of interactive, self-paced online physiology wet lab simulations used in SCO’s *Human Anatomy and Physiology* course. It is commercially-available from McGraw-Hill.

Appendix H: Responses to Interview Protocol Questions

Note: The information in this list is drawn from the handwritten notes of the interviewer. Responses are organized according to the questions from the interview protocol instrument (see Appendix F), and by respondent. The numbered bullets beside each statement correspond to the code number of the respondent who delivered it.

How did *Understanding the Cranial Nerves* impact your initial studies of the cranial nerves?

1) "It helped me understand the activities of the cranial nerves, but there was too much text to read."
2) "It was helpful to learn about the clinical testing and clinical order of testing. The module was good for its clinical applicability. However, it was scheduled too closely to the second midterm examination. We should probably have lectures over the cranial nerves too, to help us understand the material."
3) "I liked how the module guided me through the different lessons. It was much better than learning from a textbook."
4) "The module's information was comprehensive, but I felt all my studies together had the most impact."
5) "It helped a lot. It was fun, and very applicable to clinic."
6) "The module worked well as a baseline for our studies of the cranial nerves. The clinical aspect was useful."
7) "It had a positive effect. I liked the systematic presentation of material and the self-paced nature of it."

8) "The module's interactivity was beneficial. It took me about an hour to complete, but I was taking notes."

How did *Understanding the Cranial Nerves* impact your preparations for the second midterm examination in OPT 113?

1) "It helped draw connections for understanding, but it took more time to review than a regular lecture would."
2) "I had to copy/paste a lot of text to study later. You should provide a summary page to help us prepare for the exam."
3) "I just looked over the module before the midterm."
4) "When I was reviewing for the midterm, I didn't study the material as much as I would have with a normal lecture, since the module was so well-organized. I also was able to take notes extensively, a lot more than I could in a live lecture. That helped me prepare."
5) "The difficulty navigating through the module in *Moodle* made it difficult to go back and study. I just ended up copy/pasting a lot of text."
6) "I took notes from the material as I was going through it the first time, so I didn't go back and review the module. It took me 3 hours to complete with note taking."
7) "I feel like it helped me understand the material well."
8) "I just reviewed the notes I took."

How did *Understanding the Cranial Nerves* impact your performance on the second midterm examination in OPT 113?

1) "I think it had a good impact, since it helped me understand the material. It

was bad that it took up so much study time."

2) "It didn't have any different effect than a normal lecture."
3) "It's hard to say."
4) "I don't think it had any net effect."
5) "It didn't affect my performance."
6) "I definitely did better than I would have with just a lecture."
7) "It might have had a negative effect, because I felt like I understood the module so well I got a false sense of security and didn't study it enough."
8) "It was helpful with the questions that had cranial nerve details."

How did *Understanding the Cranial Nerves* impact your preparations for the final examination in OPT 113?

1) "Not as much as the midterm."
2) "I didn't review it much for the final."
3) "I just looked at it briefly before the final."
4) "I reviewed it once."
5) "Not at all."
6) "I reviewed my personal notes."
7) "I looked at it once. The foundational information I learned from the module was very useful as I studied for the final."
8) "I reviewed my notes."

How did *Understanding the Cranial Nerves* impact your performance on the final examination in OPT 113?

1) "It probably didn't."

2) "Since I didn't review it for the final, not much."

3) "I don't think I could say."

4) "It didn't have any influence."

5) "It didn't effect my performance."

6) "It was easier to remember the basics of cranial nerves."

7) "I think it had a positive effect on my performance."

8) "It helped me with my overall understanding of cranial nerves."

What impact did *Understanding the Cranial Nerves* have upon your overall experience in OPT 113?

1) "It would have been better as a normal lecture because of the personal interaction with the professor that's missing. The text-heavy lessons were less effective than if they had only been audio and pictures."

2) "The other two interactive modules were better.[1] Navigation through this module was tricky."

3) "It was one of the more memorable parts of the course. I still remember some key ideas from the module."

4) "It was better than reading or listening to a lecture, because it was self-paced and contained videos and quizzes. The other interactive modules had better flow, though."

5) "No real effect."

6) "The module helped. I think more modules like this would be good. Reading the text was better than audio narrations."

[1] This refers to two other self-paced modules used in OPT 113 course that presented the material through audio narrations, rather than text as in *Understanding the Cranial Nerves*.

7) “It would have been nice to have access to the module earlier, so we could have studied for the midterm longer.”
8) “The class was improved by it because it helped me understand each pathway specifically.”

In what ways was *Understanding the Cranial Nerves* most useful?

1) “Its presentation of the order of cranial nerve testing.”
2) “How in depth it was, and its clinical usefulness.”
3) “It helped me remember key points. It was also useful to understand clinical practices.”
4) “Its clinical relevance.”
5) “It showed how things were done clinically.”
6) “How it walked through each cranial nerve, and showed the clinical applications.”
7) “The animations and video were great. The text was more useful than audio narrations.”
8) “The pictures and videos of the different conditions.”

In what ways was *Understanding the Cranial Nerves* least useful; or how could *Understanding the Cranial Nerves* be improved?

1) “Use more audio narration and less text. Fix the navigation issues.”
2) “The navigation in *Moodle* could have been better. Don’t schedule it so close to the examination.”
3) “Navigation was tough, and I couldn’t print out the text. The videos didn’t always work right.”

4) “It took me longer to complete than I expected, abut two hours, but I did take extensive notes.”
5) “You should use a better technology than *Moodle* to present it.”
6) “Give a more realistic time reference.”
7) “The buffering on the videos took a long time. Navigation was difficult at times.”
8) “Use more pictures and cases, and less text.”

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