DEVELOPMENT OF A LEARNING MODULE FOR ULTRASOUND GUIDED REGIONAL ANESTHESIA

A DOCTORAL PROJECT
Submitted in Partial Fulfillment of the Requirements
For the degree of
DOCTOR OF NURSING PRACTICE

By
Jennifer Lynn Thompson

Doctoral Project Committee Approval:

Sass Elisha, EdD, RN, CRNA, Project Chair
Dana N. Rutledge, PhD, RN, Committee Member

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ABSTRACT

Emerging technology drives many aspects of anesthesia practice and continuing education should follow in the same path. As the practice of anesthesia evolves and new techniques are introduced, clinical providers must seek out opportunities to stay current in their practice. Numerous barriers exist that make it difficult to do this. One current example is the utilization of ultrasound guidance in regional anesthesia. There is a need for an educational resource aimed at clinical anesthesia providers that uses a multimedia approach and that is easily accessible to practitioners in teaching the basics of ultrasound guided regional anesthesia. This paper describes the design and development of a computer-assisted learning module for teaching the basics of ultrasound guidance for use in peripheral nerve blockade to clinical anesthesia providers. The design was based on the cognitive theory of multimedia learning by Richard Mayer. The module developed provides a learning opportunity to the clinical anesthesia provider without the added financial stress or time commitment of attending a professional conference for education. The module was also developed to fulfill, in some way, the special need for the use of media and technology in continuing education for the medical professional.
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ACKNOWLEDGMENTS

I would like to thank my advisor, Sass Elisha, and committee member Dr. Rutledge for their continuous guidance. Thanks to the CRNAs who contributed their time, energy and expertise in project content. To my parents, Dan and Chris, who never allowed me to believe in limitations. Thank you to my 7-year-old daughter, Ella, who inspires me to question everything and enjoy the moment. Last, to my amazing husband, Cory, whose unwavering support and love makes everything possible.
BACKGROUND

The use of ultrasound guidance to facilitate the placement of peripheral nerve blocks is a technique that is being used in health care at an ever-increasing rate. Peripheral nerve blocks offer numerous advantages over general and spinal/epidural anesthesia for specific patient populations (Antonakis, Ting, & Sites, 2011; Falyar, 2010; Laur & Weinberg, 2012). However, this method has only recently been introduced into anesthesia curriculum including that of nurse anesthetists, creating a gap in emerging clinical practice and current practitioner knowledge and skill.

Needs Assessment/Problem Statement

Currently, practicing anesthesia providers have options in clinical advancement and continuing education such as attending conferences, taking journal courses, and simply researching and studying new techniques on their own (Dickerson, 2012). While all of these are viable options, each has limitations. Barriers to professional development in nursing have been studied and major themes emerge: time constraints, financial constraints, difficulties in application of new knowledge, and lack of competency in accessing electronic evidence-based practice literature (Gould, Drey, & Berridge, 2006; Penz et al., 2007; Santos, 2012). The timing, cost and content of conferences may not be optimal for a provider who works in a rural setting or has limited options for time off. Journal courses are one-dimensional, lack the component of interactivity, and may easily lose the attention of the reader. Studying new techniques independently often proves difficult when trying to find and access dependable and accurate sources.

Accessibility adds another component to the spectrum of continuing education (Dickerson, 2012). Computer-assisted learning, otherwise known as e-learning, is a potential solution to the problem with accessibility. Computer-assisted learning (CAL)
refers to the use of electronic media and the use of information technology in education. CAL includes numerous types of media that deliver text, audio, images, animation, and streaming video, and includes technology applications and processes such as audio or video tape, satellite television, optical disc storage (e.g., CD-ROM), and computer-based learning, as well as local intranet/extranet and web-based learning. Many terms are used synonymously when referring to computer-assisted learning. These include multimedia learning, e-learning, technology-enhanced learning, computer-based instruction, computer-based training, computer-assisted instruction or computer-aided instruction (CAI), internet-based training, web-based training, online education, virtual education, virtual learning environments, and digital educational collaboration. These alternative names emphasize a particular aspect, component or delivery method (Cook, 2005; Ruiz, Mintzer, & Leipzig, 2006).

Computer-assisted learning can occur inside of or outside of the classroom (Tavangarian, Leypold, Nölting, & Röser, 2004). It can be self-paced, asynchronous learning or may be instructor-led, synchronous learning. Computer-based learning is suited to distance learning and flexible learning, but it can also be used in conjunction with face-to-face teaching. Proponents believe that computer-assisted learning have the potential to make a significant impact in education (Tavangarian et al., 2004).

Although computer-assisted training is not specifically superior to traditional textbook learning with regard to knowledge acquisition, practical benefits of computer-assisted education include the ability to standardize learning material quality and content, incorporate multimedia technology, and individualize delivery of course materials in terms of time, pace, repetition, and location (Chumley-Jones, Dobbie, & Alford, 2002; Cook, 2005; Ruiz et al., 2006). Many anesthesia providers use their smart phones or other
hand held devices to access information related to medications, diagnoses and treatment options. Emerging technology drives many aspects of anesthesia practice and continuing education should follow in the same path. Evidence supports the need for greater options in continuing education offerings. Dickerson (2012) states that technology provides flexible opportunities to obtaining new knowledge: distance learning, intranet or Internet-based sharing, and other approaches. Many of these options offer the opportunity for practitioners to gain knowledge and obtain continuing education at flexible times and with easy accessibility.

Specific to ultrasound guided regional anesthesia, there are numerous websites and applications that currently serve as resources but these are primarily aimed at anesthesia providers with some foundation of clinical knowledge on the subject. Furthermore, companies that sell specific products created many of these websites and applications; this could demonstrate bias for specific instruments and techniques.

There is a need for an educational resource aimed at clinical anesthesia providers that uses a multimedia approach and that is easily accessible to practitioners in teaching the basics of ultrasound guided regional anesthesia.

**Purpose Statement**

The purpose of this doctoral project is to develop a CAL module on the basics of ultrasound guidance for use in peripheral nerve blocks as an adjunct to clinical practice for anesthesia providers. The target learner is an anesthesia provider lacking in current knowledge on ultrasound guidance. The project objectives are to (1) create an opportunity for clinical anesthesia providers to gain knowledge in a new topic, and (2) utilize CAL in continuing education. CAL can provide an effective and safe learning environment that offers the opportunity for learners to increase their knowledge about a
particular area of practice. An anesthesia provider with a solid clinical knowledge base can successfully improve patient outcomes in these challenging clinical situations with the use of computer-assisted learning.

**Supporting Framework**

The enhancement of learning by integrating multimedia technology into instructional design is central to this project. The framework chosen to provide the theoretical underpinnings was Richard E. Mayer’s Cognitive Theory of Multimedia Learning (CTML). CTML was developed through extensive research that involved testing learning theory while focusing on authentic learning situations (Mayer, 2009, p. 3). This theory merges several concepts from both the science of learning and the science of instruction. It was constructed on the philosophy that “the design of e-learning courses should be based on a cognitive theory of how people learn and on scientifically valid research studies. In other words, e-learning courses should be constructed in light of how the mind learns and experimental evidence concerning e-learning features that promote best learning” (Mayer, 2008, p. 7).

The multimedia principle states “people learn more deeply from words and pictures than from words alone” (Mayer, 2009, p. 1). The basis for Mayer’s CTML is to target the design of instructional media to how the human mind works. Therefore, simply adding words to pictures is not an effective way to achieve multimedia learning. Figure 1 diagrams the CTML with intent to represent the human information-processing system. Four primary elements, derived from Mayer’s research, make up the CTML: (1) there are two separate channels for processing information; (2) there is limited channel capacity; (3) learning is an active process; and (4) information transfer occurs (Mayer, 2009, pp. 60-68).

**Dual-Coding Theory**

CTML relies on the dual-channel assumption, which states that learners have two primary channels of processing information—auditor and visual (Clark & Paivio, 1991). By leveraging both of these channels in an educational experience, and by linking connections between numerous representations of the same information, meaningful learning is more likely to occur (Mayer, 2008).

**Limited Capacity Working Memory**

The concept that the memory only has the ability to hold a limited amount of information at one time is supported by both Baddeley’s model of working memory (1986) and Sweller’s cognitive load theory (1988). Sensory memory is exposed to an unlimited amount of incoming information presented as both verbal and auditory stimuli; however, only a limited number of the incoming stimuli can be processed through either channel at any given time. Together, these theories suggest that the cognitive load is cumulative in nature and can affect the ability to learn (Baddeley, 1986; Sweller, 1988). CTML utilizes this idea in educational design by recommending the segmentation of instruction and restricting the use of extraneous information (Mayer, Heiser, & Lonn, 2001).
Active Processing

The concept of active processing defines learning as a continuous process of filtering, selecting, organizing, and integrating information (Mayer, 2008). The selected information is organized into distinct cognitive representations. This step is a rate-limiting step and consumes a significant amount of time, until an appropriate cognitive representation emerges that accurately represents elements of the selected verbal and auditory stimuli. In his book, *Multimedia Learning*, Mayer states: “Perhaps the most crucial step in multimedia learning involves making connections between word-based and image-based representations” (2009, p. 70).

Information Transfer

Information transfer relies on the concept that meaningful learning has occurred (Mayer & Johnson, 2008). If meaningful learning takes place, learners are able to access newly acquired knowledge from their long-term memory when needed in order to perform a specific task. Information transfer is further divided into near-transfer and far-transfer. Near-transfer refers to knowledge that is used immediately after learning it. Far-transfer is for knowledge that is needed some time after learning it (Mayer & Johnson, 2008).

When aiming the design of education on the science of learning, three key elements are fundamental: (a) reducing extraneous cognitive load, (b) managing essential processing, and (c) fostering generative learning (Mayer, 2009, p. 79-82). These three elements comprise what Mayer identifies in his book as the 12 primary principles of multimedia instruction as explained below.

Principles for Reducing Extraneous Processing

The problem with most ineffective multimedia lessons is that they cause the
learner to engage in extraneous processing, which wastes precious cognitive capacity but does not help the learner build an appropriate cognitive representation (Mayer, 2008).

1. **Coherence Principle**: People learn better when extraneous material is excluded from a multimedia lesson rather than included.

2. **Signaling Principle**: People learn better when essential material is highlighted.

3. **Redundancy Principle**: People learn better from animation and narration without text than from animation with narration and text, except when the onscreen text is short, highlights the key action described in the narration, and is placed next to the portion of the graphic that it describes.

4. **Spatial Contiguity Principle**: People learn better when corresponding words and pictures are presented close rather than far from each other on the page or screen.

5. **Temporal Contiguity Principle**: People learn better when corresponding narration or words and animation are presented simultaneously rather than successively (i.e., the words are spoken or printed at the same time they are illustrated in the animation).

**Principles for Managing Essential Processing**

When the material is too complex, the demands of essential processing could overwhelm the learner. Complexity is determined by the number of elements and the relationship between them (Mayer, 2008).

6. **Segmenting Principle**: People learn better when a narrated animation is presented in learner-paced segments rather than as a continuous presentation.

7. **Pretraining Principle**: People learn better from a narrated animation when
they already know the names and characteristics of essential components.

8. Modality Principle: People learn better from graphics with spoken text rather than graphics with printed text.

**Principles for Fostering Generative Learning**

When extraneous processing is reduced and the managing of essential processing has taken place, the learner has cognitive capacity available for generative learning (Mayer, 2008).

9. Multimedia Principle: People learn better from words and pictures than from words alone. This allows people to build connections between their verbal and pictorial models.

10. Personalization Principle: People learn better from a multimedia lesson when words are in conversational style rather than formal style. If people feel as though they are engaged in a conversation, they will make more effort to understand what the other person is saying.

11. Voice Principle: People learn better when narration is spoken in a friendly, human voice rather than a machine voice.

12. Image Principle: Adding the speaker’s image to the screen on a multimedia lesson does not necessarily help people to learn better.

(Mayer, 2008; Mayer, 2009, pp. 266-273; Mayer, 2010; Mayer, Griffith, Jurkowitz, & Rothman, 2008; Mayer, Heiser, & Lonn, 2001; Mayer & Johnson, 2008; Mayer & Scott, 2012).
REVIEW OF LITERATURE

Overview

The literature search was executed with the main focus on the benefits of computer-assisted learning modules for educating the anesthesia provider about regional anesthesia. A comprehensive search of the literature was conducted using PubMed, CINAHL, PsycINFO, and Cochrane. Key terms initially searched included “computer-assisted learning,” “web-based learning,” “e-learning,” AND “ultrasound guided regional anesthesia.” There were no limits put on years; however, a restriction was set to exclude articles in languages other than English. Three articles resulted from this search. One article addressed the use of a web-based course for teaching ultrasound-guided regional anesthesia in emergency medicine physicians (Bretholz, Doan, Cheng, & Lauder, 2012). Bretholz and colleagues studied the effects of a web- and simulation-based ultrasound course on the comfort level of physicians in performing ulnar and femoral nerve blocks, and whether their comfort levels were maintained one month after the course. Authors of the second article discussed web-based regional anesthesia education in anesthesiology residents but did not specifically address the use of ultrasound guidance (Kopp & Smith, 2011). The third article examined the value of adding a web-based ultrasound simulator tutorial to a traditional lecture on regional anesthesia (Wegener et al., 2013).

Search terms were modified using the same search engines. The new search terms included combinations of the following key terms: “computer-assisted learning,” “e-learning,” “computer learning module,” “computer-based learning,” “web-based learning,” “internet-based learning,” AND “healthcare professional,” “anesthesiologist,” “anesthetist,” “anesthesia,” “regional anesthesia,” and “ultrasound guidance.” These
articles were limited based on language, irrelevance and studies published from 2003 and later. Abstract scanning identified 57 articles to be retrieved for further evaluation. These articles were further limited based on irrelevance or poor design and methodology. Of the remaining 14 articles, 11 specifically involved students. Only 4 articles addressed the use of computer-assisted education in healthcare professionals.

**Utilization of Computer-Assisted Learning in Clinician Education**

Knowledge levels increase with computer-based education just as when traditional face-to-face directed education is given (Abdelhai, Yassin, Ahmad, & Fors, 2012; Alemen, Carillo de Gea, & Mondejar, 2011). However, much of the research done on this topic in healthcare is focused on the student or patient as the learner. Few studies include the clinical practitioner as a learner or involve teaching clinical anesthesia techniques.

Studies on the use of web-based modules in ultrasound-guidance for healthcare practitioners did not consistently reveal an increase in learners’ knowledge and skill when compared to traditional teaching methods (Bretholz et al., 2012; Kopp & Smith, 2011; Wegener et al., 2013; Wutoh, Boren, & Balas, 2004). A study designed to evaluate whether an electronic tutorial could improve accuracy and speed of performance in anatomy identification for novice anesthesia providers revealed significantly higher accuracy scores but a longer time requirement for the experimental group (Wegener et al., 2013). Bretholz et al. (2012) concluded that although practitioner comfort level and intention to use ultrasound guidance for peripheral nerve blocks was increased immediately following a web-course, this increased comfort and intention was not maintained one month after the course. Kopp and Smith (2011) studied 43 anesthesiology residents randomly assigned to type of education on regional anesthesia:
traditional lecture versus web-based modules. Results demonstrated equal performance on knowledge post-tests. While the researchers did not find the results they anticipated, they succeeded in characterizing anesthesia residents as highly visual learners owing to the fact that residents felt strongly that online learning should be included in every aspect of education (Kopp & Smith, 2011).

Although the benefits of anesthesia-specific education with learning modules versus traditional education are not convincing as to superiority over other methods, the research is sparse and learner comments on attitudes towards computer-assisted modules were overwhelmingly positive suggesting there is value in its use (Bretholz et al., 2012; Kopp & Smith, 2011; Wegener et al., 2013). A review of 16 studies compared internet-based interventions to traditional formats for Continuing Medical Education (CME). These studies involved both physicians and professional students. All studies demonstrated either no difference or an increase in knowledge levels between the experimental and control groups (Wutoh et al., 2004).

Two studies on web-based learning focused on nurses as learners. Dennison (2011) concluded that although nephrology nurses with greater than three years of experience demonstrated similar pre and post-test scores after taking a computer-assisted learning module, novice nurses showed an improvement of more than 20% between pre and post-test scores after reviewing the module. The authors concluded that computer-assisted learning should be viewed as an effective strategy in the education of nurses for unfamiliar topics or tasks. Harrington and Walker (2004) reported higher knowledge scores in staff after receiving computer-based training compared with instructor-led training. Additionally, participants reported that they enjoyed the computer-based training and had no difficulty using the technology.
The use of multimedia learning methods in medical education has been shown an effective adjunct to traditional education demonstrating either similar or increased post-education knowledge (Abdelhai et al., 2012; John, 2013). Studies in nursing education have shown similar results (Aleman et al., 2011; Bloomfield, While, & Roberts, 2008). Other studies support the use of computer-based learning in lieu of traditional skills and anatomy laboratories, which tend to be financially restrictive (John, 2013).

While research on students does not directly represent practicing clinicians, some similarity may be argued when considering that practitioners may be novices in certain areas of focus or techniques. Additionally, while the creation of a learning module for ultrasound guidance is the purpose of this project, the intent is not to create experts in the field, but to increase interest and share knowledge in the technique meanwhile introducing computer-assisted modules as a viable educational method.

**Use of Ultrasound Guidance for the Placement of Peripheral Nerve Blocks**

In the ambulatory surgery setting, the choice of anesthetic and postoperative analgesic techniques have a significant impact on both the length of hospital stay and the frequency of unplanned hospitalization, and consequently, the overall cost of the surgery (Liu & John, 2010). As a result, the current health care climate requires cost-analysis to be a part of all decisions that practitioners make in practice (Liu & John, 2010).

In more invasive outpatient surgeries, the routine use of general anesthesia without the use of peripheral nerve blocks as the centerpiece of a multimodal analgesic plan is commonly associated with the following costly outcomes: (1) post anesthesia care unit (PACU) admission; (2) multiple nursing interventions for pain and postoperative nausea and vomiting; (3) PACU and same-day surgery discharge delays; and (4) unplanned hospital admission (Williams, 2007). Recent evidence has supported
the use of peripheral nerve blocks for intraoperative and postoperative pain relief in appropriate surgical candidates to potentially alleviate some of these negative outcomes (Gelfand et al., 2011; Kline, 2011; McCartney et al., 2010; Orebaugh, Kentor, & Williams, 2012) Since the 1970s, peripheral nerve blocks have become standard in the multimodal pain approach. Although numerous techniques have been utilized, the electrical nerve stimulator has been the gold standard for nerve localization in regional anesthesia for the past 30 years. However, with recent developments in high-frequency imaging, the use of ultrasound (US) technology has significantly changed the practice of anesthesia and is quickly becoming the new gold standard in practice for the placement of peripheral nerve blocks (Helwani et al., 2012; Kline, 2011).

In practice, electrical nerve stimulation (NS) is used extensively to facilitate and enhance peripheral nerve block performance. By providing an objective estimate of needle-to-nerve distance, nerve stimulation enables practitioners to deposit local anesthetic with a high degree of precision. The technique capitalizes on physiology that allows electrical current passing from the needle tip to depolarize a mixed nerve without causing a painful sensory response. As the needle is guided closer to the nerve, less current is required to elicit a motor response of equal magnitude. This relationship serves to approximate needle-to-nerve distance. Whereas NS is straightforward in concept and widely applied, the fundamental principles surrounding this technique are complex and not without limitations (Orebaugh, Kentor, & Williams, 2012).

Despite the clinically reproducible success in NS techniques, controversy exists regarding the ideal current end point, whether minimum current thresholds can be a reliable predictor of needle-to-nerve distance and intraneural needle placement, and the effect of disease states on a targeted end point (Marhofer, Harrop-Griffiths, Kettner, &
The association between current magnitude and motor response is neither 100% sensitive nor specific in determining needle-to-nerve distance. Additionally, a complex biological environment impacts the relationship between needle and nerve. The conductivities of skin, nerves, muscles, adipose tissue and fascia are all different. Boundaries between layers also modify the surrounding electrical field and because current follows the path of least resistance, fluids and blood can alter current flow and prevent uniform distribution. These limitations can result in nerve damage and paralysis from intraneural injection or direct needle trauma, local anesthetic toxicity from unintentional intravascular injection, and the need to provide general anesthesia to a high-risk patient (McCartney et al., 2010).

Ultrasound systems are available that can deliver high-frequency (10MHz or higher) sound waves offering the high axial resolution required for visualization of nerves, which distinguishes them from surrounding anatomic structures (Kline, 2011). The size, depth, and precise location of many nerves in the surrounding environment can be determined with correct interpretation of the visual image. Visualization of the moving needle, once inserted an appropriate angle and within the plane of the US probe, as well as local anesthetic spread, provides valuable assistance to the anesthesia provider (Kline, 2011). The proposed benefits of US guidance over NS technique include improved block success and completeness, reduced block placement and onset times, fewer vascular punctures, prolonged duration of blocks, less procedure related discomfort, less time to learn the technique, and less local anesthetic required (Gelfand et al., 2011; Orebaugh et al., 2012; Singh, Kelly, O’Brien, Wilson, & Warner, 2012; Veneziano, Rao, & Orebaugh, 2012).
METHODS

The development of the learning module began with an evaluation of existing software that is used to create modules. Software was evaluated based on its capability to allow for the creation of a module that follows the CTML framework. Determination of benefits and potential limitations of each were identified during this process.

Review of three standard texts on ultrasound-guided peripheral nerve blockade, in addition to numerous peer-analyzed research articles were reviewed for content to be included in the module. A committee of content experts was selected to establish a consensus on content that should be included in the module. John Dellaripa is a Certified Registered Nurse Anesthetist (CRNA) who has been actively utilizing US in the placement of peripheral nerve blocks for over 5 years. He is not only considered an expert amongst his anesthesia colleagues and surgeons but teaches US guidance to students during clinical rotations. He has also participated as a clinical expert in US workshops conducted by professional anesthesia organizations. Lieutenant Commander (LCDR) Stephanie Duffy is also a CRNA who actively practices US guidance, teaches US guidance to student anesthetists, and actively participates as a clinical expert and instructor in professional workshops. Mano Shanaa, MD is an anesthesiologist who actively practices US guidance, teaches US guidance to student anesthetists, and serves as the Kaiser Permanente Woodland Hills anesthesia department’s resource person for anything that involves US guidance. Following discussion with these experts and review of the literature, an outline for the module was developed.

Following content approval and outline development, pictures and ultrasound images were selected and permission for use was obtained or original drawings were created. Content experts reviewed all original drawings and editing was done as needed.
Following content and picture approval, the design process of the computer module began, utilizing the principles of the CTML. The module contains words, pictures, and videos, which stimulate the auditory and visual sensory memory (Appendix B). This combination fosters the processing of information and integration of long-term and working memory. Upon completion of the design, content experts reviewed the module and editing was done as needed.

**Ethical Considerations**

The focus of this project was to develop an educational tool that can be used by clinical anesthesia providers. It involved the translation of research into practice application and therefore did not require Institutional Review Board (IRB) approval.

**Project Implementation/Time Line of Activities**

The following steps represent the timeline followed in order to complete the US module.

1. Selected content experts- 9/1/13
2. Met with content experts- 10/1/13
3. Listed criteria desired for software selection- 10/1/13
4. Explored currently available computer-assisted learning modules- 10/15/13
5. Met with content experts- 11/17/13
6. Final decisions made on what content was to be included- 12/1/13
7. Met with artist for original artwork development and gained permission for other photos as needed-1/15/13
8. Final product- 2/25/14
9. Present module to content experts for final evaluation- 3/1/14
10. Module published to iBook- 3/10/14
Organizational Setting

The development of this project did not occur within any patient care area and did not involve a specific patient population. It did, however, focus on educating clinical anesthesia providers in best-practice techniques and promotes quality patient care. This project has the potential to be disseminated in the future to practitioners through the American Association of Nurse Anesthetists and used for educating anesthesia students at the Kaiser Permanente School of Anesthesia.

Stakeholders Involved

This project was completed due to the support of numerous people. They are identified as the project stakeholders.

- Jennifer Thompson- Doctoral candidate, project author and developer
- Sass Elisha, CRNA, EdD- Doctoral committee chair, adult education expert
- Dana Rutledge, RN, PhD- Doctoral committee member
- John DellaRipa, CRNA, MSN- content expert
- LCDR Stephanie Duffy, CRNA, DNP- content expert
- Mano Shanaa, MD- content expert

Resources Used for Project Completion

The resources required for the completion of this project are listed below.

1. Appropriate hardware and software to develop module
   a. Macintosh computer (currently own)
   b. Apple iPad (currently own)
   c. iBooks Author software- free download
2. Financial resources to compensate medical artist for drawings ($1200)
3. Involvement of content experts for review and recommendations
a. Three formal meetings with each expert (approximately 9 hours total)
b. Numerous “mini-consult” sessions with each expert (approximately 12 hours total)

4. Involvement of project chair for continuous evaluation
5. Consultation with Kaiser Permanente School of Anesthesia information technology (IT) department as needed
6. Video/photo editing and voice recording (approximately 72 hours)
7. Clinical photography sessions for module content utilization (approximately 6 hours)

**Evaluation Method**

The identified content experts evaluated the computer-assisted learning module to ensure that the basic principles of ultrasound guidance were clearly and thoroughly explained. Additionally, five CRNAs with experience in ultrasound guidance were asked to evaluate the module’s content and usability as outlined in the 12 principles of multimedia instruction by Mayer (2009). These principles were introduced to the content experts prior to their evaluation and questions were answered as needed (Appendix C). While recognizing that a review by content experts and clinical CRNAs with experience in the subject may provide different results than a review by anesthesia providers without prior subject knowledge, this was necessary for content integrity. In order to further evaluate the module, in the future, it will be presented to both anesthesia students and clinical CRNAs who have received no prior education on ultrasound guided peripheral nerve blocks for review.
PROJECT PRODUCT

The final product of this project is a prototype module created in iBook Author entitled Ultrasound Guidance: Basic Principles. The module was created for anesthesia providers with little to no experience in ultrasound guided regional anesthesia. In no way does the product certify nor qualify an inexperienced provider to practice ultrasound guided regional anesthesia. It instead serves as a didactic introduction to a topic that requires hands-on experience and clinical proctoring to master. Upon completion of this module, the learner will have a better understanding of the basic principles of ultrasound guidance including the physics of ultrasound and techniques to enhance ultrasound imaging. The module can be downloaded on the Kaiser Permanente School of Anesthesia website (www.kpsan.org). The iBook includes text in paragraph form, narrated videos, drawings, ultrasound images, animated drawings, slide-sets, and interactive images (Appendix B).
CONCLUSIONS

Throughout the development of this learning module, many lessons were learned. Numerous difficulties arose, and most of the frustrations involved technology and the format that was chosen. Upon reviewing multiple sources to potentially use for the module design, iBook Author, a software program produced by Apple Inc., was chosen. It was chosen for its ease of usability for the reader and its ability to be advertised and distributed. Additionally, the Kaiser Permanente IT department recommended iBook Author due to its security and ease of review by the developer along with ease of updating the material. Creating and editing video without previous knowledge and skills in these areas added a large amount of additional work and time to the project. Additionally, obtaining usable ultrasound images that demonstrated anatomy and block placement well was also problematic and time consuming. In creation future additional modules, engaging the assistance of an expert in this technology would be very helpful.

The plan for this product is to present it to the American Association of Nurse Anesthetists (AANA) education department with hopes that they will recognize the need for this material and possibly advertise it through their website or journal. Additionally, there is hope that the AANA will identify the need for continuing education on this subject and allow CRNAs to earn continuing education units for completing the module.
REFERENCES


APPENDIX A

PERMISSION TO USE MODEL

From: Rich Mayer rich.mayer@psych.ucsb.edu
To: Jen L Thompson/JenLThompson@kp.org
Date: 02/20/2014 11:25 AM
Subject: Re: CTML inquiry

Thanks for your kind words. You certainly have my permission to use the figure for scholarly purposes. I do not know of a tool for evaluating e-learning although several organizations (such as ASTD) have developed guidelines and criteria. I think the best evaluation is to measure student learning outcomes as our goal is to promote learning and performance. Best wishes, Rich

On Feb 20, 2014, at 9:37 AM, JenL.Thompson@kp.org wrote:

Dr. Mayer,

I am in the final stages of completing my doctorate in nursing practice and have utilized your CTML as the framework for my final project. I have thoroughly enjoyed researching the science of learning and I believe your theory serves as an excellent guide to develop e-learning modules (which is part of my project). I would love to use a figure that demonstrates the theory within the text of my paper but would, of course, need your permission to do so. Additionally, I would also like to ask you if you’ve created, or know of a good evaluation tool that can be used to evaluate e-learning? Any guidance or support would be greatly appreciated. You have unknowingly, served as a mentor to me for my project through your extensive research and publications.

Many thanks for your time and expertise.

Regards,

Jennifer L. Thompson, MSN, CRNA
Kaiser Permanente School of Anesthesia
Didactic and Clinical Instructor
(626) 564-3027
APPENDIX B

OUTLINE OF MODULE

Chapter 1 Ultrasound Guidance: Basic Principles

Section 1 Physics

Ultrasound defined
Ultrasound is acoustic energy defined as the longitudinal progression of pressure changes. Ultrasound waves are created by converting electrical energy into acoustic energy. When electrical current is applied to a piezoelectric material, such as used in an ultrasound transducer, a shape change occurs and causes it to vibrate. These vibrations emit ultrasound waves.

Ultrasound is a form of mechanical sound energy that travels through a conducting medium as a longitudinal wave producing alternating compression (high pressure) and rarefaction (low pressure).

Characteristics of Ultrasound
All sound waves, including ultrasound, can be described by seven characteristics. These are period, frequency, propagation speed (velocity), amplitude, power, intensity, and wavelength. To enhance the image, the provider can manipulate some of these sound wave properties (Table 1.1).

Table 1.1 Characteristics of Ultrasound

<table>
<thead>
<tr>
<th>Wave Characteristic</th>
<th>Definition</th>
<th>Modifiable</th>
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</thead>
<tbody>
<tr>
<td>Period</td>
<td>Time it takes to complete 1 cycle</td>
<td>No</td>
</tr>
<tr>
<td>Frequency</td>
<td>Number of cycles per second</td>
<td>Yes</td>
</tr>
<tr>
<td>Propagation Speed/Velocity</td>
<td>Speed that a sound wave moves through something</td>
<td>No</td>
</tr>
<tr>
<td>Amplitude</td>
<td>Magnitude of the wave</td>
<td>Yes</td>
</tr>
<tr>
<td>Power</td>
<td>Strength of the wave</td>
<td>Yes</td>
</tr>
<tr>
<td>Intensity</td>
<td>Concentration of energy in a sound beam</td>
<td>Yes</td>
</tr>
<tr>
<td>Wavelength</td>
<td>Distance that 1 cycle of sound occupies</td>
<td>No</td>
</tr>
</tbody>
</table>

Generation of an Ultrasound Wave
An ultrasound wave is generated when an electric field is applied to an array of piezoelectric crystals located on the surface of a transducer. Electrical stimulation causes mechanical distortion of the crystals resulting in vibration and production of sound-waves (i.e., mechanical energy). The conversion of electrical to mechanical energy is called the converse piezoelectric effect.

Each piezoelectric crystal produces an ultrasound wave. The summation of all waves generated by the piezoelectric crystals forms the ultrasound beam. Ultrasound waves are generated in pulses and each pulse commonly consists of 2 or 3 sound cycles of the same frequency (Movie 1.1). The pulse length (PL) is the distance traveled per pulse. Waves of short pulse lengths improve axial resolution for ultrasound imaging. Pulse Repetition Frequency (PRF) is the rate of pulses emitted by the transducer (number of pulses per unit time). Ultrasound pulses must be spaced with enough time between pulses to permit the sound to reach the target of interest and return the transducer before the next pulse is generated.
Movie 1.1 Generation of an Ultrasound Wave

Generation of an Ultrasound Image
An image is generated when multiple piezoelectric crystals inside a transducer rapidly vibrate in response to an alternating current. Ultrasound travels into the body where, on contact with various tissues, it can be reflected, refracted, and scattered. The echoes of the sound waves emitted are received by the ultrasound probe (piezo-electric crystal) and an image is produced.

The transducer waits to receive the returning wave (i.e., echo) after each pulsed wave. The transducer transforms the echo (mechanical energy) into an electrical signal which is processed and displayed as an image on the screen. The conversion of sound to electrical energy is called the piezoelectric effect.

The image can be displayed in a number of modes:
- amplitude (A) mode
- brightness (B) mode
- motion (M) mode

B-mode is the mode traditionally used for regional anesthesia. This mode provides real time imaging of structures that are clearly discernible. M-mode is a way of viewing the acoustic characteristics over time. It is a layering of returned ultrasound waves stacked next to each other. This mode does not have much utility for anesthesia providers.

Ultrasound transmission
As the ultrasound beam travels through tissue layers, the amplitude of the original signal becomes attenuated as the depth of penetration increases. Attenuation (energy loss) is due to:

1. **Scatter** reflection- occurs when the incident wave encounters a surface that is not perfectly smooth. Echoes from diffuse reflectors are generally weaker than those returning from specular reflectors. Scattering also occurs when the wavelength of the ultrasound is larger than the dimensions of the reflective structure. The reflected echo scatters in many different directions resulting in echoes of similar weak amplitudes. Ultrasonic scattering gives rise to much of the diagnostic information we observe in medical ultrasound imaging.

2. **Transmission**- the decreasing intensity of the sound beam as it passes through the medium. It is the result of energy absorption of tissue and the reflection and scatter that occur between boundaries of tissue with different densities.

3. **Refraction**- is a change of direction of the transmitted beam. Refraction occurs only when the speeds of sound are different on each side of the tissue interface. The degree of beam change (bending) is dependent on the change in the speed of sound traveling from one medium on the incident side to another medium on the transmitted side. With medical imaging, fat causes considerable refraction and image distortion, which contributes to some of the difficulties encountered in obese patients. Refraction encountered with bone imaging is even more significant leading to a major change in the direction of the incident beam and image distortion.

4. **Specular reflection**- occurs at flat, smooth interfaces where the transmitted wave is reflected in a single direction depending on the angle of incidence. Examples of specular reflectors are fascial sheaths, the diaphragm, walls of major vessels, and block needles (Movie 1.2).
Movie 1.2 Ultrasound Transmission

The **angle of incidence** is also a major determinant of reflection. An ultrasound wave hitting a smooth mirror-like interface at a 90 degree angle will result in a perpendicular reflection. An incident wave hitting the interface at an angle less than 90 degrees will result in the wave being deflected away from the transducer at an angle equal to the angle of incidence but in the opposite direction. When this happens, the signal of the returning echo is weakened and a darker image is displayed. This explains why it is difficult to visualize a needle inserted at a steep angle (> 45 degrees to the skin surface).

**Tissue Echogenicity**

The image produced by the ultrasound machine depends on both the tissue’s density and its ability to reflect ultrasound waves back to the transducer (tissue echogenicity). Strong specular reflectors appear as hyperechoic structures on ultrasound image, and are those with a greater propensity to reflect ultrasound energy. Weaker diffuse reflections produce hypoechoic images, which tend to absorb energy. No reflection produces anechoic images, the ultrasound beam passes easily through without significant reflection. Hyperechoic structures appear brighter on the screen, hypoechoic structures appear darker, and **anechoic** structures appear darkest (Table 1.2).
Table 1.2 Tissue Echogenicity

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Ultrasound Image Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Veins</td>
<td>anechoic (compressible)</td>
</tr>
<tr>
<td>Arteries</td>
<td>anechoic (pulsatile)</td>
</tr>
<tr>
<td>Muscle</td>
<td>mixture of hyperechoic lines with a hypoechoic background</td>
</tr>
<tr>
<td>Tendons</td>
<td>predominately hyperechoic</td>
</tr>
<tr>
<td>Bone</td>
<td>hyperechoic lines with a hypoechoic shadow</td>
</tr>
<tr>
<td>Fat</td>
<td>hypoechoic with irregular hyperechoic lines</td>
</tr>
<tr>
<td>Nerves</td>
<td>hyperechoic or hypoechoic (depending on location)</td>
</tr>
</tbody>
</table>

Table 1.2 Characteristics of Tissue on Ultrasound

Hyper-echoic - dense tissues are poor conductors of sound and appear bright
Hypo-echoic - fluid and less dense tissues allow sound waves to pass through them more readily and appear dark

Anisotropy refers to a change in echogenicity of tissues as a result of transducer angle. A hyperechoic nerve structure can appear hypoechoic when the angle of incidence is changed from 90 degrees to 45 degrees (see transducer movement).

Frequency and Image Resolution

Spatial resolution determines the degree of image clarity. Resolution is the ability of the ultrasound machine to distinguish two structures that are close together as separate. Spatial resolution is influenced by axial and lateral resolution, both of which are closely related to ultrasound frequency. Axial resolution refers to the ability to distinguish two structures that lie along the axis of the ultrasound beam as separate and distinct. Axial resolution is determined by the pulse length. A high frequency wave with a short pulse length will yield better axial resolution than a low frequency wave.

Lateral resolution refers to resolution of objects lying side by side. Lateral resolution is directly related to the transducer beam width, which in turn is related to the ultrasound frequency. A high frequency transducer emits a wave with a short wavelength and a small beam width. Lateral resolution is poor when the 2 structures lying side by side are located within the same beam width. Because the returning echoes overlap with each other side by side, the 2 structures will appear as one on the display. It is therefore clinically important to choose the highest frequency transducer possible to keep the beam width as narrow as possible in order to provide the best possible lateral resolution. However, attenuation also increases with frequency thus one must find a balance between resolution and attenuation.

The beam width can be further reduced by adjusting the focal zone (FZ). Lateral resolution is the best at the FZ, where the beam is narrowest. It is therefore clinically useful to focus the target structure within the focal zone to yield the best possible lateral resolution. The beam is known to diverge as it propagates deep into the far field (Figure 1.1).
Ultrasound waves penetrate tissues to different depths based on the probe frequency. Higher frequency probes, which emit waves at a frequency between 5 and 13 MHz, provide images with greater resolution but do not penetrate deeply into tissues. Lower frequency probes, with frequencies between 2 and 5 MHz, can penetrate tissue deeply (up to a depth of 30 cm), but the resolution is far less than that of high frequency probes.

Color doppler is an instrument to characterize blood flow. For ultrasound guided regional anesthesia, color doppler is useful for differentiating vascular from nonvascular structures. The Doppler effect occurs when there is a moving source and a stationary listener. There is an apparent change in the returning echoes due to the relative motion between the sound source and the receiver. If the source (blood) is moving towards the receiver, the perceived frequency is higher (red) and when the source is moving away from the receiver, the perceived frequency is lower than the actual display (blue). It is important to note that color doppler detection of flow is poor when the transducer is perpendicular (90 degrees) to the vessel and best with the transducer is parallel (0 degrees) to the blood flow (Gallery 1.1)
Section 2 Image Optimization

Identifying the Target
Knowledge of anatomy is fundamental to the safe practice of regional anesthesia. The provider must take advantage of a real time anatomical examination every time the transducer is placed on the patient. A complete and systematic anatomical survey should be performed in the region. It is important to visualize structures that should not be trespassed (i.e., the pleura, the subclavian artery). Nerves may not be readily visible at the first glance but vessels, muscles and bones are easily identifiable under ultrasound. These structures will help to define the target nerve location.

Views and Approaches
The ultrasound image generated relies on the direction the transducer (probe) is placed over structures. Most peripheral nerve blocks are performed by visualizing the short axis of the nerve (cross-section). Knowledge of anatomy is necessary to accurately produce the image desired. It is conventional to orient the transducer marker to the right side of the subject examined during a transverse scan and orient cephalad during a longitudinal scan.

Probe Orientation
The direction the ultrasound probe is oriented in relation to the desired subject matter will generate variability in the axis view (Gallery 2.1).

Gallery 2.1 Probe Orientation

Needle Orientation
Peripheral nerve blocks can be performed utilizing an in-plane or an out-of plane approach. These two approaches refer to the place of the needle in relation to the transducer. Most peripheral nerve blocks are performed utilizing an in-plane approach, allowing for visualization of the entire needle length. In-Plane- This technique produces an image of the entire needle, most importantly the tip, as it is directed to a particular structure. This is done by first obtaining an image and then placing the needle under the narrow or side portion of the probe.
It should be noted that the ultrasound beam is very thin. If the needle travels outside the beam, it will not be seen. The in-plane technique allows the performance of regional blocks with greater safety and helps reduce the incidence of accidental vascular puncture or nerve contact. **Out-of-Plane**- This technique allows visualization of the needle as a dot crossing the ultrasound beam. This technique is popular for vascular access, as it produces an image of the vessel in cross section. This also allows for angle variation, because imaging is not intended to see the length of the needle. The out-of-plane technique is accomplished by first obtaining an image, then introducing the needle under the beam plane in the middle of the wide portion of the probe. It is useful to place the target in the middle of the screen (Movie 2.1).

**Movie 2.1 Needle Orientation**

**Example 1: Locating the Brachial Plexus for an Interscalene Block (Gallery 2.2)**

1. Place the transducer in an oblique plane on the neck.
2. Identify the cross section of the carotid artery (pulsating) and the jugular vein (compressible).
3. Locate the sternocleidomastoid muscle.
4. Identify the anterior scalene and the middle scalene muscles.
5. The brachial plexus is consistently sandwiched between the anterior and middle scalene muscles and will appear as hypoechogenic structures.

**Gallery 2.2 The Brachial Plexus**
Example 2: Locating the Sciatic Nerve in the Popliteal Region (Gallery 2.3)
1. Place the transducer in an oblique plane 4-6 inches above the popliteal crease.
2. Identify the femur, the popliteal artery, the semitendinosus and semimembranosus (ST/SM) medially, and the biceps femoris (BF) laterally.
3. The sciatic nerve is consistently superficial to the femur, superficial and lateral to the popliteal vessels and between the muscle layers.
4. Slightly angle the transducer caudad to capture a clearer nerve image.

Gallery 2.3 The Sciatic Nerve

Managing the Transducer
It is best to gently rest the arm holding the transducer on the patient’s body or bed to maintain hand steadiness and avoid fatigue while scanning.
There are 3 primary probe maneuvers that allow the clinician to best visualize the target structures. These maneuvers are referred to as the A-R-T maneuvers (Movie 2.2).

Movie 2.2 The A-R-T Maneuvers
Basic Components of the Machine
Ultrasound machine include three different modes: Amplitude (A-mode), Brightness (B-mode), and Motion (M-mode). Among the 3 modes, the B-mode is most commonly used for ultrasound guided regional anesthesia. There are 5 basic components of an ultrasound scanner that are required for generation, display and storage of an ultrasound image.

1. Pulser- applies high amplitude voltage to energize the crystals
2. Transducer- converts electrical energy to mechanical (ultrasound) energy and vice versa
3. Receiver- detects and amplifies weak signals
4. Display- displays ultrasound signals in a variety of modes
5. Memory- stores video display

Image Adjustments (Knobology)
There are a variety of methods that allow the provider to improve the image and increase visualization to the target structures. Having a fundamental understanding of the buttons common to all ultrasound machines and function of each will allow for the best possible image (Image 2.1).

Image 2.1 Knobology

Gain (brightness) describes the machines interpretation of the returning echo strength. When the gain is increased, the returning echo is strengthened thereby allowing for greater visualization of structures (Gallery 2.4). This is helpful when imaging deep structures as echo strength is often lost at depth. Excessive increase in gain will add “noise” to the image.

Gallery 2.4 Gain

Some of the poor visualization issues can be corrected by simply setting the focal length correctly. Imaging a structure in the ultrasound beam’s focal zone will produce the best image. This is where the beam is most concentrated and clarity is enhanced (Movie 2.3).
It is important to select appropriate depth setting according to the target nerve location. Improper depth settings will cause the image to be blurry and have poor resolution. It is best to select the highest frequency transducer possible for the required depth of penetration. A higher frequency transducer (10-12 MHz) provides the best image resolution for superficial structures. Higher frequency transducers have a limited depth of penetration (less than 3-4 cm deep). A lower frequency transducer (less than 7 MHz) is required to image deep structures, and will result in lower resolution. Curved transducers often generate lower frequency waves compared to linear transducers thus providing images of lower resolution (Image 2.2).

**Image 2.2 Frequency**

To compensate for attenuation, it is possible to amplify the signal intensity of the returning echo. The degree of receiver amplification is called the gain. Increasing the gain will amplify only the returning signal and not the transmit signal. An increase in the overall gain will increase brightness of the entire image,
including the background noise. Preferably, the **time gain compensation (TGC)** is adjusted to selectively amplify weaker signals returning from deeper structures.

The doppler will produce a dynamic, colorful image. Fast moving, pulsatile flow can be differentiated from the low velocity form of venous flow. Doppler flow is interpreted by measuring the velocities of moving blood cells. Flow toward the transducer produces higher frequencies with shorter wavelengths, while flow away from the probe elicits lower frequencies with longer waves. The difference in these sent and received waves is known as doppler shift. The shift is either positive or negative. This is then superimposed as color onto a grey 2D image, to produce a dynamic picture. Doppler mode assists in distinguishing vessels from other structures. The flow of blood is usually denoted by the colors of red and blue. Red generally indicates flow toward the transducer, and blue away from the transducer. There is currently no industry standard for this indication and it may vary from unit to unit.

**Section 3 Practical Considerations**

**Advantages of Ultrasound**

- Reveals the nerve location and the surrounding vascular, muscular, bony, and visceral structures.
- Validates external landmarks against internal anatomy.
- Provides real-time imaging guidance during needle advancement allowing for purposeful needle movement and proper adjustments in direction and depth (Movie 3.1).

**Movie 3.1 Needle Advancement**

- Images the local anesthetic spread pattern during injection
- Improves the quality of sensory block, the onset time, and the success rate compared to nerve stimulator techniques (as shown in some clinical studies).
- Reduces the number of needle attempts for nerve localization which may prove to reduce risk of nerve injury.
- Differentiates extravascular injection from unintentional intravascular injection.
- Differentiates extraneural injection from unintentional intraneural injection.
- Allows the performance of blocks without a reliance on motor stimulation which may be painful on traumatic injuries or post-operative patients.
Limitations of Peripheral Nerve Stimulation

- Peripheral nerve stimulation (PNS) guidance is useful only when a motor response can be elicited.
- Nerve Stimulation provides objective but indirect evidence of nerve location.
- Evidence of proper needle placement through a motor response disappears after injection of 1-2 mL of local anesthetic.
- Motor response achieved at less than 0.5 mA does not guarantee a successful or complete block.
- PNS does not prevent intravascular, intraneural or pleural puncture.
- Elicitation of a motor response may be painful for a patient with a traumatic injury.

Interscalene Block

- Most reliable and dense on the upper trunks/roots (C5-7) and sensory anesthesia of the cervical plexus (C2-4)
- Primarily used for shoulder and upper arm surgery
- Use caution in patients with severe respiratory compromise as the phrenic nerve is often blocked causing transient hemi-diaphragmatic paralysis
- Not a reliable block for surgery distal to the elbow as the ulnar nerve (C8 and T1) is usually spared
- Horner’s syndrome (hoarse voice, ipsilateral ptosis and nasal congestion) is a common side effect

Movie 3.3 Interscalene Block

Popliteal Block

- Block of the sciatic nerve (L4-S3) near its divergence into the tibial and the common peroneal nerve
- Provides coverage for surgery of the foot and ankle leaving only saphenous nerve distribution uncovered
Femoral Block

- Used for surgery of the anterior thigh and knee and the medial aspect of the lower leg
- The femoral nerve is reliably located just lateral to the femoral artery.
APPENDIX C

INFORMATION SHARED WITH CRNA EVALUATORS FOR MODULE EVALUATION

Principles for Reducing Extraneous Processing

1. Coherence Principle: People learn better when extraneous material is excluded from a multimedia lesson rather than included.

2. Signaling Principle: People learn better when essential material is highlighted.

3. Redundancy Principle: People learn better from animation and narration without text, than from animation with narration and text, except when the onscreen text is short, highlights the key action described in the narration, and is placed next to the portion of the graphic that it describes.

4. Spatial Contiguity Principle: People learn better when corresponding words and pictures are presented close rather than far from each other on the page or screen.

5. Temporal Contiguity Principle: People learn better when corresponding narration or words and animation are presented simultaneously rather than successively (i.e., the words are spoken or printed at the same time they are illustrated in the animation).

Principles for Managing Essential Processing

6. Segmenting Principle: People learn better when a narrated animation is presented in learner-paced segments rather than as a continuous presentation.

7. Pretraining Principle: People learn better from a narrated animation when they already know the names and characteristics of essential components.

8. Modality Principle: People learn better from graphics with spoken text rather than graphics with printed text.

Principles for Fostering Generative Learning

9. Multimedia Principle: People learn better from words and pictures than from words alone. This allows people to build connections between their verbal and pictorial models.

10. Personalization Principle: People learn better from a multimedia lesson when words are in conversational style rather than formal style.
11. Voice Principle: People learn better when narration is spoken in a friendly, human voice rather than a machine voice.

12. Image Principle: Adding the speaker’s image to the screen on a multimedia lesson does not necessarily help people to learn better.

(Mayer, 2008; Mayer, 2009, pp. 266-273; Mayer, 2010; Mayer, Griffith, Jurkowitz, & Rothman, 2008; Mayer, Heiser, & Lonn, 2001; Mayer & Johnson, 2008; Mayer & Scott, 2012).
APPENDIX D

TABLE OF EVIDENCE FOR PROPOSAL

Summary of Studies Including Computer-based Learning and Ultrasound Guidance in Peripheral Nerve Blocks

<table>
<thead>
<tr>
<th>Author, Year, Purpose</th>
<th>Design, Key Variables</th>
<th>Sample &amp; Setting</th>
<th>Measurements</th>
<th>Key Findings</th>
<th>Author Conclusions, Study Limitations, Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdelhai, R., Yassin, S., Ahmad, M. F., &amp; Fors, U. G. (2012).</td>
<td>Prospective interventional study. IV: traditional lecturing, e-learning course. DV: learning experience, quiz results.</td>
<td>Students in a medical school in Egypt taking a course in Reproductive Health.</td>
<td>Pre and post quizzes, course experience questionnaire, focus group discussions.</td>
<td>Improved quiz scores in the e-learning group (p &lt; .001), students in the e-learning course perceived the course to be easier than students in the control group (p &lt; .001), satisfaction rates in the e-learning course exceeded 95%; students in the e-learning course recorded higher mean instructor ratings, clear set goals ratings and appropriate workload ratings.</td>
<td>E-learning offers learners materials for self-instruction and collaborative learning. Major potential for providing more flexible access to course content and instructions. Asynchronous discourse is inherently self-reflective and therefore more conducive to deep learning, than is synchronous discourse. Limitations: Students in e-learning group were not prevented from attending the traditional lecture, students volunteered to participate in e-learning, could not assess retention of knowledge.</td>
</tr>
<tr>
<td>Author, Year, Purpose</td>
<td>Design, Key Variables</td>
<td>Sample &amp; Setting</td>
<td>Measurements</td>
<td>Key Findings</td>
<td>Author Conclusions, Study Limitations, Notes</td>
</tr>
<tr>
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<td>----------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>Alemen, R., Yassin, S., Ahmad, M., &amp; Fors, U. G., (2012).</td>
<td>Prospective, interventional. IV: learning method DV: learner knowledge.</td>
<td>University of Murcia, nursing school. Sample included 116 students enrolled in a second-year course on medical-surgical nursing.</td>
<td>Baseline knowledge pre-test, Post-test immediately following completion of module, 10-week follow up post-test.</td>
<td>Students in the CAL group produced significant cognitive gains in the immediate follow-up test. Both teaching methods resulted in similar knowledge retention in the 10-week follow-up test.</td>
<td>Benefits of CAL included the ability to assess understanding throughout a learning module, a decrease in workload for instructors and the promotion of independent learning and reflective thinking.</td>
</tr>
<tr>
<td>Bloomfield, J. G., While, A. E., &amp; Roberts, J. D., (2008).</td>
<td>Integrative Review. IV: Learning method DV: Skill performance; Cognitive recall; Knowledge and skill retention; Learner satisfaction.</td>
<td>12 research-based studies published in English between 1997 and 2006.</td>
<td>Evaluation of skill performance by assessors, Knowledge tests, evaluation of satisfaction levels with method of learning.</td>
<td>Overall effects of CAL on skill performance were positive; mixed results were reported for the effect of CAL on cognitive recall; high levels of learner satisfaction were reported with CAL.</td>
<td>Limitations in design flaws included: lack of control for incidental learning or maturation effects, small sample size, no random assignment, post-test only design, no quantitative data, not comparative, little attempt to control for confounding variables.</td>
</tr>
<tr>
<td>Bretholz, A., Doan, Q., Cheng, A., &amp; Lauder, G. (2012).</td>
<td>Non-randomized, experimental design. IV: web-based tutorial and half-day simulation program DV: comfort level and intention to use US-guided nerve blocks.</td>
<td>11 pediatric emergency physicians in a hospital classroom.</td>
<td>Pre and post-course surveys.</td>
<td>Participants reported that it addressed their learning needs and they would consider advanced training. Comfort level and intent to use US-guided blocks increased immediately after course. Neither increase was sustained one month after the course.</td>
<td>These techniques can increase comfort level and intention to use US guidance immediately after but may not sustain over time. The need for follow-up training was identified. Participants reported that they would partake in refresher courses, particularly if offered once per year.</td>
</tr>
<tr>
<td>Author, Year, Purpose</td>
<td>Design, Key Variables</td>
<td>Sample &amp; Setting</td>
<td>Measurements</td>
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<tr>
<td>Dennesin, H. A. (2011).</td>
<td>The creation, implementation and analysis of computer-assisted learning modules for the nephrology nurse learner.</td>
<td>Module aimed at non-expert nephrology nurses.</td>
<td>Percentage of score improvement from pre- to post-test and compared amongst nurses of varying years of experience. A heuristic evaluation of the learning modules was completed by five individuals that were deemed experts.</td>
<td>An improvement of more than 20% was noted between the pre- to post-test scores of the non-expert nurses after reviewing the module.</td>
<td>CAL can be an effective strategy in the education of nephrology nurses. Limitations: small sample size, no randomization.</td>
</tr>
<tr>
<td>Gelfand, H. J., Ouanes, J. P., Lesley, M. R., Ko, P. S., Murphy, J. D., Sumida, S. M., Isaac, G. R., &amp; Kumar, K. (2011).</td>
<td>Meta-analysis of 16 RCTs. IV: US guided technique, nerve stimulation technique, landmark technique, transarterial technique DV: Success rates for upper and lower extremity PNBs.</td>
<td>1,264 subjects in the 16 RCTs. 13 studies included a sample of 20-115 adults, 3 studies included a sample of 20-25 children. The Johns Hopkins University, Baltimore, MD.</td>
<td>Success rate: defined as anesthesia sufficient for surgery without supplementation either with general anesthesia or additional nerve block. Nerve stimulation technique: utilization of a nerve stimulator to locate nerve Landmark technique: Transarterial technique: utilization of an artery to approximate nerve location as evidenced by blood aspiration.</td>
<td>Significant increase in the overall success rate for blocks performed using US guided technique vs. non-US techniques. In addition, significant increase in success for all but one specific block.</td>
<td>Subject size in many studies were small, the definition of “success” is somewhat arbitrary from study to study.</td>
</tr>
<tr>
<td>Author, Year, Purpose</td>
<td>Design, Key Variables</td>
<td>Sample &amp; Setting</td>
<td>Measurements</td>
<td>Key Findings</td>
<td>Author Conclusions, Study Limitations, Notes</td>
</tr>
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<tr>
<td>Harrington, S. S., &amp; Walker, B. L. (2004).</td>
<td>Randomized two-group pretest-posttest. IV: instructor led training and computer based training DV: content knowledge, attitudes and practice.</td>
<td>Nine nursing facilities in Texas, South Carolina, Georgia, Minnesota, Idaho and Virginia. 1294 staff members.</td>
<td>Pretest and posttest scores compared between computer-based and instructor-based groups.</td>
<td>Both groups significantly increased scores from pretest to posttest. Knowledge gains were higher in the computer group. Participants reported that they enjoyed the computer based training and had no difficulty using the computers.</td>
<td>Use of CAL addresses the problem of having large numbers of staff away from their duties at one time for training by having small groups attend computer based sessions rather than one large instructor led group. Limitations: inadequate methods of measuring training effects on actual practices.</td>
</tr>
<tr>
<td>Helwani, M. A., Saied, N. N., Asaad, B., Rasmussen, S., &amp; Fingerman, M. E. (2012).</td>
<td>Exploratory study. Variables investigated: Number of PNBs performed, the role of US guidance, the barriers to its use, methods by which teaching physicians acquired their experience.</td>
<td>American Board of Anesthesiology-accredited residency programs. 82 responses (132 surveys sent). Vanderbilt University School of Medicine.</td>
<td>Survey questions included: Number of PNBs performed weekly, location (upper vs lower), type (single injection vs continuous catheter), and technique (US vs not), primary reasons for using/not using US.</td>
<td>Regional anesthesia workshops and learning from other colleagues were the primary methods of learning PNBs. Main reasons for lack of use of US included: lack of expertise, time constraints, US equipment not available, and need to teach alternative techniques.</td>
<td>Most anesthesia residents are receiving an increased exposure to US guidance and programs view US guidance as the “gold standard” for PNB placement.</td>
</tr>
<tr>
<td>John, L. J. (2013).</td>
<td>Review on CAL in undergraduate pharmacology.</td>
<td>23 studies included. 15 research articles, 2 review articles, and 6 editorials.</td>
<td>Advantages: Promotes active and self-directed learning. Meets learning objectives. Can supplement lectures and enable learners to self-study. Experiments/informat</td>
<td>Disadvantages: limits the direct interaction with living tissue. CAL is expensive in the initial stages. Development of CAL is labor intensive. Technical snags may be encountered. Developing software requires support of</td>
<td>Computer assisted learning is a feasible and very effective teaching and learning method in pharmacology with huge potential to change the way of learning as it meets the majority of learning objectives.</td>
</tr>
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<td>Kopp. S. L., Smith, H. M. (2011). Purpose: to analyze the benefits of a web-based education program in regional anesthesia.</td>
<td>RCT IV: Web-based module and traditional textbook-style module DV: knowledge performance scores on RA techniques.</td>
<td>43 anesthesiology residents at the Mayo Clinic College of Medicine.</td>
<td>Knowledge pretest, postmodule knowledge assessment, index of learning styles assessment, participant satisfaction survey.</td>
<td>All residents scored higher on the postmodule knowledge assessment regardless of the individual learning style utilized. Satisfaction scores showed a preference for Web-based learning in education.</td>
<td>Although scores are not statistically significant, satisfaction through web-based learning was expressed.</td>
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<td>Singh, A., Kelly, C., O’Brien, T., Wilson, J., &amp; Warner, J. (2012). Purpose: To evaluate the safety, efficacy, and patient satisfaction associated with ultrasound-guided interscalene block.</td>
<td>Prospective study Variables: patient satisfaction, presence of adverse events.</td>
<td>Orthopedic Ambulatory Surgery Center at Mass General West, Waltham, Massachusetts.</td>
<td>Efficacy of blocks: number of hours of sensory block as reported by patient. Complications: admission to ER, ear numbness, nausea, difficulty voiding, shortness of breath, neuropraxia, incomplete block.</td>
<td>2.88% rate of transient complications noted overall. May have been attributed to ISB but could have been attributed to other causes. 97.8% of individuals reported that they would elect to have another US guided ISB if surgery was required in the future.</td>
<td>Study supports the use of US guided interscalene blocks. Limitations: no control group therefore results could only be compared with other studies on adverse event and patient satisfaction with nerve stimulation techniques.</td>
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<td>Wegener, J. T., van Doorn, C. T., Eshuis, J. H., Hollmann, M. W., Preckel, B., &amp; Stevens, M. F. (2013). Purpose: Investigation of whether an electronic tutorial could improve accuracy in identification of anatomical structures.</td>
<td>RCT IV: standard US machine, US machine with electronic tutorial DV: test scores and time required to identify structures.</td>
<td>Academic Medical Center Amsterdam. 35 residents and anaesthesiologists with little or no experience in UGRA.</td>
<td>Identification of 27 anatomical structures at 4 predefined levels of the brachial plexus. Groups were compared with regards to scores and time required at each anatomical structure, Tutorial group scored significantly higher in accuracy but required more time to identify structures.</td>
<td>A significant increase in correct identification was gained by utilization of the tutorial as compared to the control group.</td>
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<td>Author, Year, Purpose</td>
<td>Design, Key Variables</td>
<td>Sample &amp; Setting</td>
<td>Measurements</td>
<td>Key Findings</td>
<td>Author Conclusions, Study Limitations, Notes</td>
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<td>accuracy or speed of performance in identifying anatomical structures.</td>
<td>Review of MEDLINE, CINAHL, ACP Journal club, and the Cochrane Database.</td>
<td>Studies included: RCTs of internet-based education in which participants were practicing health care professionals or health professionals in training.</td>
<td>Measurements were categorized according to the nature of the intervention, sample size, and other information about educational content and format.</td>
<td>Studies comparing web versus print showed higher scores in the web-based groups. In web versus didactic interventions, studies were inconclusive. However, subjective commentary from participants in all studies was favorable towards web-based education.</td>
<td>Internet-based CME programs are just as effective in imparting knowledge as traditional formats of CME. Changes in practice are difficult to assess.</td>
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</table>

Note. IV = independent variable; DV = dependent variable; CAL = computer assisted learning; US = ultrasound; PNBs = peripheral nerve blocks; RCT = randomized controlled trial; RA = regional anesthesia; ISB = interscalene block; UGRA = ultrasound-guided regional anesthesia; CME = continuing medical education.