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Elaboration and Question Strategy Effect on Learning Outcomes and Cognitive Load

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ELABORATION AND QUESTION STRATEGY EFFECT ON LEARNING OUTCOMES AND COGNITIVE LOAD

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ABSTRACT

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The purpose of this study was to investigate the effects of instructor-created elaborations, learner-created elaborations and adjunct questions on learning outcomes in an asynchronous learning environment, using pre-recorded video. The study also investigated the effects of instructor-created elaborations, learner-created elaborations, or adjunct questions on perceived cognitive load. The effect of learning strategy on quality of elaboration was also investigated. Results showed no significant difference in learning outcomes or cognitive load or quality of elaboration, but a post-hoc analysis revealed a significant difference in intrinsic cognitive load for students who used generative strategies while having no gain in learning outcomes.

This dissertation is dedicated to my mom, son, and daughter who just would not let me quit.

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I look back on the last eight years and grieve great losses of personal and academic heroes. My larger than life father passed away about halfway through this long journey, leaving my family without our fearless leader and me without a rudder. The journey to completion of this dissertation required me to navigate uncharted waters of independence while rebuilding my ship. Losses from the academic community continued to buffet me with the passing of Roxana Moreno in 2010. Her intrepid spirit and research in multimedia learning inspired me to find my own academic voice as a female. In 2012, David Jonassen, who generously shared his time and wisdom with peons like us at conferences, passed away and a large portion of the constellations in my night sky went dark. My Polaris through this whole journey has been my daughter, Rachel Simmons who provided content expertise, educational expertise, moral support, and the final inspiration to complete the journey by enrolling in a Ph.D. program herself. I survived the journey with the help of many people whom I wish to acknowledge.

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CHAPTER I

INTRODUCTION

As the economic forecast for expenditures in education darkens, the call for efficiency in instructional technology grows more fervent (Molenda, 2009). Using technology for instruction that consumes both the development and delivery time of faculty and the use of mental resources of learners is both inefficient and unproductive, even if the desired learning outcomes are achieved (Molenda, 2009). Modes of delivery such as synchronous video streaming, lecture capture, or asynchronous video offer the convenience of virtual class attendance and the additional benefit of having class recordings available for review at any time. However, these delivery modes often require extensive institutional resources for bandwidth, server storage space, and personnel to maintain the system. Additionally, the designs of video based instruction often do not involve consideration of learner mental resources or the inclusion of instructional strategies to promote learning. This lack of consideration of instructional strategies and effective message design within the affordance of the delivery technology can interfere with learning outcomes (Anglin & Morrison, 2002; Grabowski, 2004). The choice of using asynchronous video over another delivery mode would no more increase learner performance than choosing to use a different type of truck to deliver groceries would increase the nutrition in food (Clark, 1994).

Instead of focusing on the delivery mechanism, a focus on choosing instructional strategies within the instruction deliver mode of video such as generative learning may yield positive learning results. Generative learning strategies work by creating relationships and meaning in restructuring information (Grabowski, 2004; Jonassen, 1988; Wittrock, 1974, 1990, 1992). Quantitative research studies have shown an increase in learning when using generative strategies such as note-taking, highlighting, concept mapping and answering adjunct questions, but the results of elaboration, or examples is less clear (Grabowski, 2004). Elaborations involve learners either creating examples or studying provided examples and the research provides evidence that either type may or may not be an effective generative learning strategy (Anderson & Reder, 1979; Divesta & Peverly, 1984; Johnsey, Morrison & Ross, 1992; Mayer, 1980; Moreno & Mayer, 2005; Reder, 1979; Stein & Bransford, 1979). The efficacy of the elaborations is mainly dependent on alignment with objectives (Stein & Bransford, 1979) and integration of previous knowledge (Grabowski, 2004). Even when the objectives are aligned and the integration of previous knowledge exists, no difference between types of elaboration may exist (Johnsey, Morrison & Ross, 1992). The research in cognitive load theory provides further guidance to designers by suggesting the incorporation of generative learning strategies such as self-reflection when applicable (Chi, De Leeuw, Chiu & Lavancher, 1994). Evidence indicates the self-reflection principle increases learning by requiring the learner to use cognitive resources in explaining relationships between interacting units of information (Sweller, Ayres & Kalyuga, 2011).

Medical education is looking for ways to decrease lecture based instruction and move toward independent learning which is the self-assessment of learning needs; independent identification, analysis, and synthesis of relevant information; and appraisal of the credibility of information sources, (LCME, 2016). Traditionally, medical student education during the pre-clinical years of medical school involved rote memorization of basic science facts but now accrediting bodies are promoting independent learning, engaged learning, and situated learning. Methods such as case based learning and the more structured team based learning (TBL), encourage learners to take more responsibility for their learning and provide a more integrated approach to basic science learning rather than rote memorization of facts. Presentation of concepts may take place in a flipped environment. Flipped learning includes short visual (not text based) presentations that are viewed in video format by individual learners before attending a learning event such as case based or TBL. The learning events of case based or TBL are application based and are synthesizing in nature. Medical education is struggling to embrace these new learning methods that support collaborative learning such as TBL, and flipped learning as a way to move away from traditional didactic lectures (Pluta, Richards & Mutnick, 2013). Part of the struggle stems from a lack of common definitions for types of learning and from how to appropriately engage medical students in the new types of learning (Pluta et al, 2013). The struggle in medical education to move beyond lecture is exacerbated by the lack of positive outcomes (Pluta, et al., 2013). This study will investigate ways to improve learning with generative strategies as a way to prepare for active learning events. The purpose of this study is to examine the effects of generative strategies that promote active processing when using instructional asynchronous video.

Review of the Literature

There is a call for quantitative research examining effects of design on instructional materials (Brunken, Plass, & Moreno, 2010,). This call guides developers toward a more effective use of instructional strategies within the affordance of the selected delivery mode to achieve desired learning outcomes. This review of the literature will explore the use of recorded video in medical education and the use of strategies by comparing the impact of generative learning strategies on learning outcomes.

Medical Education

In the move away from traditional lecture toward more effective methods of learning, medical education has engaged numerous methods with varying levels of success in an effort to actively engage learners. The quest for active learning is driven by the accrediting body, the Liaison Committee to Medical Education's (LCME) and its sponsoring organization, Association of American Medical Colleges, (AAMC). The LCME is comprised of instructional design professionals as well as medical professionals.

Recorded videos are used to prepare learners for events like team based learning (TBL) (Prober & Khan, 2013). The primary focus of the study is on the use of generative learning strategies with recorded video. While TBL is not the focus of this study, this study is focusing on the most effective use of recorded lectures to prepare learners for active learning events such as TBL.

Team Based Learning is defined for medical education by AAMC as:

> A form of collaborative learning that follows a specific sequence of individual work, group work and immediate feedback; engages learners in learning activities within a small group that works independently in classes with high learner-faculty ratios (Medbiquitous, 2012, p. 5).

TBL is effective for small group learning in medical anatomy because it requires learners to regularly prepare for class. The individual and group activities included in TBL incorporate feedback on learner performance and are given the chance to develop higher order thinking (Nieder, Parmelee, Stolfi, & Hudes, 2005). A new way to support TBL has emerged in the form of using of recorded video to prepare learners for the small group learning in TBL (Prober & Khan, 2013). This use of recorded video is now referred to as flipped learning. Perhaps because it is very new, there is no definition for flipped learning from Medbiquitous, but Prober & Khan (2013) define it as:

> Lessons previously taught in class are learned at home, and "homework" is performed in the classroom in collaboration with peers and guided by teachers. The pace of learning is guided by the individual learner and the relevance of the material is underscored through in-class problem solving (p. 1407).

The collaborative learning event of TBL requires learners to come to the event prepared with foundational knowledge. An increasing number of medical schools are utilizing recorded lectures to supplement learner learning of foundational knowledge in the first and second years of medical school (AAMC, 2013). Flipped learning utilizes short videos, either gleaned from lecture videos or created anew, to prepare learners with foundational knowledge before participating in a TBL (Prober & Khan, 2013). Generative learning strategy research has shown a positive effect on learning outcomes when compared to no strategy use (Anderson & Reder, 1979; Divesta & Peverly, 1984; Johnsey, Morrison & Ross, 1992; Mayer, 1980; Moreno & Mayer, 2005; Reder, 1979; Stein & Bransford, 1979). The inclusion of the generative learning strategy of elaborations in learning with video is hypothesized to improve learning over no elaborations and learning from video alone. In a study utilizing flipped learning in a pharmacology class, the first offering of videos did not include any generative learning and the instructors found the learners to be unprepared for class. In the second offering, the videos were be accompanied by questions (a form of generative learning) to ensure the learners are acquiring the necessary knowledge before coming to class and participating in collaborative learning activities (Mclaughlin, Roth, Glatt, Bharkholonarehe, Davidson, Grinffin, Esseran & Mumper, 2014). In a second year pathology course utilizing TBL, lower performing learners benefited from working with better prepared learners (Koles, Nelson, Stolfi, Parmelee & DeStephen, 2005). The more prepared learners have a better experience with collaborative learning because they have not synthesized the to-be learned material. The LCME is encouraging medical schools to use collaborative learning experiences. The utilization of generative learning strategies with recorded video may be one way to prepare learners for collaborative learning experiences.

Generative Learning Strategies

Generative learning strategies provide opportunities for learners to actively create associations that facilitate the development of knowledge. Generative learning involves learners generating an understanding of the instructional material while doing tasks such as underlining, paraphrasing, concept mapping, answering adjunct questions or completing elaborations (completing examples) (Jonassen, 1988; Wittrock, 1974, 1990, 1992). The generative learning strategy of elaboration under the correct circumstances has shown evidence of enhanced learning (Anderson & Reder, 1979; Divesta & Peverly, 1984; Johnsey, Morrison & Ross, 1992; Mayer, 1980; Moreno & Mayer, 2005; Reder, 1979; Stein & Bransford, 1979). Effective use of the generative learning strategy of elaboration depends on the type of elaboration (Anderson & Reder, 1979; Divesta & Peverly, 1984; Johnsey, Morrison & Ross, 1992; Mayer, 1980; Moreno & Mayer, 2005; Reder, 1979; Stein & Bransford, 1979), the use of self-reflection during elaborations (Chi, De Leeuw, Chiu & Lavancher, 1994), and the expenditure of cognitive resources used in the process (Sweller, Ayres, & Kalyuga, 2011). During the learning process, associations are generated by constructing activities that allow learners to link prior experience to new information (Wittrock 1974). According to Grabowski (2004), if there is restructuring of information either organizationally or formation of integrated relationships, then learning is generative. Given this definition, activities such as highlighting, underlining or answering adjunct questions may not be generative unless there is evidence that the learner is covertly integrating prior knowledge.

Grabowski (2004) divides generative strategies into two distinct categories, coding and integration strategies. An example integration strategy would be an elaboration while examples of coding generative strategies would be underlining, note taking, highlighting and of particular interest in this study, adjunct questions. These strategies would only be considered generative if they require the learner to integrate prior knowledge.

Adjunct Questions. Adjunct questions are categorized as coding generative by Grabowski (2004), are questions inserted into instruction to facilitate learning (Linder & Rickards, 1985) and are considered a form of generative learning as long as the adjunct question requires the learner to integrate prior knowledge (Grabowski, 2004). Martyn, (2009) directs designers to use questions as the first of seven principles of good practice to make recorded lectures interactive. Adjunct questions are a “low hanging fruit” designers reach for when seeking to make asynchronous video interactive. In order for the generative strategy of adjunct questions to bear fruit, the questions need to be crafted according to evidence-based principles (Andre, 1979; Grabowski, 2004; Rickards, 1979). Research on adjunct questions has typically been conducted using text-based instructional materials either in print or on the computer (Rothkopf, 1965; Rothkopf & Billington, 1974; Rothkopf & Bisbicos, 1967; Frase, 1968; Mayer, 1975; Rickards & Divesta, 1974). In his study, Rothkopf (1965) investigated the mathemagenic effect on learning of adjunct questions originally as a way to shape the learner’s reading behavior. Research shifted from lower-level verbatim questions to higher-level questions in order to discover the nature of the cognitive processing activities (Rickards, 1979). It is in the higher level questions that the efficacy and generative nature of adjunct questions is found.

The generative power of adjunct questions depends on the type, frequency, position, if they promote organizational activities and if are written at an appropriate level of learning (Andre, 1979; Grabowski, 2004; Rickards, 1979). Generally, application level questions inserted periodically into the material will yield the best results (Andre, 1979; Rickards & Denner, 1978; Rickards, 1979). Application level questions require learners to choose from a set of examples (Krathwohl, 2002). Designers are also encouraged to use real world examples (Martyn, 2009). After the initial consideration to use the low hanging fruit of adjunct questions (Martyn, 2009), one of the next choices a designer could use is examples, or elaborations.

Elaborations. Elaborations clarify the learner's prior knowledge and experience with newly presented information (Hamilton, 1989; Jonassen, 1988; Wittrock, 1974). Elaboration strategies are the best examples of generative processing (Jonassen, 1988) and are examples that can be of two different types; learner-created or instructor-created. Elaborations are thought to work because they increase redundancy of information stored and increase the number of contextual elements between the encoding and retrieving content (Hamilton, 1989). Instructor-created elaborations are subject matter expert examples of the topic at hand. Learner-created elaborations are created by the learner in an attempt to integrate previous knowledge with new knowledge (Hamilton, 1989). Elaborations are categorized as integration activities while adjunct questions are categorized as integration generative activities (Grabowski, 2004).

Instructor-created elaborations. Instructor-created elaborations are a type of example created by the instructor and/or subject matter expert. These created examples provide learners with the opportunity to study a completely correct worked out example of the topic at hand. Instructor-created elaborations do not always increase learning and in some cases have been found to harm retention of verbal information from text (Allwood, Wikstrom & Reder,1982; Reder & Anderson, 1980) because the focus was not on the targeted learning objectives. Instructor-created elaborations on computer skills improved learning for generated syntax examples but did not improve conceptual learning (Reder, Charney & Morgan, 1986). Targeting the objectives to be learned, Stein and Bransford (1979) showed that focusing the instructor-created elaborations on the objectives were helpful in the retention of verbal information. Instructor-created elaborations have been shown to facilitate learning under specialized conditions such as high prior knowledge (Rothkopf & Billington, 1974) or when the elaborations were more precise and clarified objectives (Stein & Bransford, 1979).

Learner-created elaborations. Learner-created elaborations require learners to add their own understanding of a topic to create an example. Learner-created elaborations have shown to improve retention of verbal information (Arkes & Freedman, 1984; DiVesta & Peverly, 1984; Dooling & Christianson, 1977). Mayer (1980) investigated learner-created elaborations in problem solving specifically with computer programming skills. Mayer's (1980) research investigated two types of learner-created elaborations and found both to be effective in helping learners apply concepts and solve problems. One group compared new material to a model and the other group compared new pieces of information to each other. Both treatment groups utilized learner-created elaborations by including a form of self-explanation to scaffold the learner during elaboration creation. The results showed that learner-created elaborations were effective in low-ability and low prior knowledge subjects. Learner-created elaborations worked in this case because the learner engaged in two cognitive processes (Mayer, 1980). First, the learner searched for prior knowledge and actively related their prior knowledge to the new information presented. The second cognitive process was the addition of self-explanation. The elaboration group outperformed the control group Mayer (1980). Self-explanation works by requiring the learner to answer "why" questions or explain the process they used to arrive at an answer (Chi, De Leeuw, Chiu & Lavancher, 1994). Spontaneous self-explanations do not always come easily (Renkle, 1997) and eliciting self-explanations improves learning outcomes and learners with low prior knowledge received more benefit from elicitation (Renkle, 1999). Prompting learners to self-explain each step of a probability problem improved performance (Renkle, Atkinson, Maier & Staley, 2002). It is clear from the literature that self-explanation works but unclear as to what form of elaboration works best. Using elaborations will yield improved learning over no elaborations but the literature is still unclear as to what type of elaboration is best. Johnsey, Morrison & Ross, (1992) found no difference between learner-created elaborations and Instructor-created elaborations. Self-explanations can be successfully used with worked examples (Sweller, 2010) given the learners have sufficient cognitive resources to self-explain. The conditions governing cognitive resources involved in elaborations and self-explanation might be found in cognitive load theory (Sweller, Ayres & Kalyuga, 2011). If the cognitive load does not exceed the capacity of the learner's resources, then the learner will have the ability to create examples and self-explain during the process. In order to design elaborations with self-explanation, an understanding of cognitive load theory is required.

Training to Use Strategies. Selecting appropriate strategies such as learner-created examples or instructor-created examples, depends on prior knowledge of the learner and the nature of the material to be learned (Wittrock, 1990). Fiorella & Mayer (2015) summarized empirical studies on the strategies using summarizing, concept mapping, drawing, imaging, self-testing, self-explaining, and enacting while reporting on the varying types of training and varying lengths of time used for training. According to Wittrock's (1989) generative learning theory, the selection of strategy should be based on prior knowledge and nature of material, the type of material and the time for training. Fiorella & Mayer, (2015) recommended verbal strategies such as summarizing, self-testing, self-explaining, and teaching for non-spatial material and strategies such as mapping, drawing, imagining, and enacting for spatial material. The training time spent for these strategies varied based type of material and on learner prior knowledge. For middle school learners using the summary strategy, 6 hours of training was required (Bean & Steenwyk, 1984). For undergraduate students using the mapping strategy, 5 hours of pre-training was used (Holley, Dansereau, McDonald, Garland, & Collins, 1979). During an undergraduate hypermedia lesson on the circulatory system, 30 minutes of training on self-regulated learning was required (Azevedo & Cromley, 2004). In an undergraduate lesson on structured query language, using the instructor-created examples strategy, Catrambone, &Yuasa, (2006), found learners spent an average of 19 minutes using a training manual. In an undergraduate lesson on accounting using instructor-created examples, Stark, Mandl, Gruber & Renkle, (2002) used a 20-minute training with modeling and demonstration of using a worked example.

In medical education, the call by accrediting agencies to include active learning strategies is behind the use of generative learning strategies. Active learning strategies may also be generative learning strategies. For example, studying flashcards is like studying instructor provided examples, and creating flashcards is like learner-created examples. In studies specific to the discipline of anatomy, (Patil & Iver, 2016; Bow, Dattilo, Jonas & Lehmann, 2013; Haynes, Gaglani, Wilcox, Mark, Mitchell, Terence, DeLeon, Goldberg, 2013), no training was provided to learners creating or studying flashcards. Various generative strategies employed during flipped learning where the learner watches a video before attending an active learning session provided some training to students in the form of instructions in the syllabus or reading a brief article on the strategy prior to strategy use (McLaughlin, Roth, Glatt, Gharkholonarehe, Davidson, Griffin, & Mumper, 2014; Parmelee, Michaelsen, Cook, & Hudes, 2012).

Training learners to use generative strategies is needed for all strategies and should be based on type of material to be learned and learner prior level of knowledge, (Fiorella & Mayer, 2015). Previous empirical studies for undergraduate level and above learners ranged from 19 to 30 minutes (Azevedo & Cromley, 2004; Catrambone & Yusa, 2006; Stark, Mandle, Gruber & Renkle, 2002).

Cognitive Load Theory

The guiding principles of cognitive load help us understand how mental resources interact during learning. These principles provide prescriptions for designers to facilitate meaningful learning in instructional environments. Cognitive load theory involves two types of load, intrinsic and extraneous. Intrinsic load involves the nature of the material such as calculus or physics because of the higher interaction between elements. The high interaction between elements means a change in one concept may affect many other elements in numerous ways. Extraneous load involves the way information is presented; such as a poorly designed interface that delivers instruction. Intrinsic and extraneous loads combine leaving resources for the learner to use that are labeled germane resources. Germane resources are used for essential processing. The involvement among the types of cognitive load when learners are processing information determines the efficacy of the instruction. If the germane resources left are not enough, then the learner will not be able create schema.

Using the principles of cognitive load theory, instructional designers can manage the limitations of working memory and maximize the extensive capabilities of long term memory. The nature of the material determines the load imposed on the working memory of an individual (Sweller et al. 1998). Intrinsic cognitive load is affected by the level of element involvement (Sweller et al., 1998). Some subjects are easy to learn because each element can be learned independently such by itself such as learning the alphabet. Other subjects have a higher element interactivity that requires the learner to understand relationships between elements before learning the material and this high element interactivity makes the subject more difficult to learn. An example of a subject with high element interactivity is a physics time and distance problem. While it is not possible to directly affect intrinsic cognitive load, there is research to support indirect manipulation of intrinsic cognitive load by using the strategy of sequencing in the instructional design process (Sweller et al, 2011). The design or layout of instruction, clarity of directions, or redundancy of instruction are example items that contribute to extraneous cognitive load. Poor layout or unnecessary bells and whistles in design can increase extraneous cognitive load and waste learner resources. Resources used in navigating a complicated interface, for example, could be used for essential processing of information. High extraneous cognitive load results in reduced resources available for schema construction while low extraneous cognitive load results in increased availability of working memory resources. Extraneous cognitive load is affected by instructional design decisions in message design and interface design. Research in elimination of unnecessary information, placement of diagrams and text have shown to reduce extraneous cognitive load in the domains of engineering, computer programming, and mathematics (Chandler & Sweller, 1991, 1996; Kalyuga, Chandler & Sweller, 1999; Sweller et al. 1998). Germane processing is the resources devoted to processing germane information after the consumption of resources from intrinsic and extraneous loads. If the intrinsic and extraneous load is additively too high, then the learner will lack the necessary working memory to form schema for understanding (Sweller, Ayres, Kalyuga, 2011; Kirschner, Sweller, & Clark, 2006; vanMerrienboer & Clerk, de Croock, 2002).

Effects in cognitive load theory. Sweller, et. al. (2011) proposed several techniques to deal with cognitive load. The worked example effect discourages the means-end style of problem solving, reduces cognitive load and facilitates schema construction. An instructor-created elaboration in anatomy is a case that contains all the steps involved in solving a problem regarding an area of the body. Worked examples focus the learner on the steps of the problem solution. Identifying important features of the worked examples for the learner to attend will improve the learner's experience with the worked example (Anderson, Boyle, Corbett, & Lewis, 1990). The important features in a worked example or instructor-created elaboration can be attended to through the use of self-explanation. In the domains of algebra, statistics, geometry, and programming, using worked examples is beneficial to learning outcomes (Cooper & Sweller, 1987; Sweller & Cooper, 1985; Paas, 1992; Paas & vanMerrienboer, 1994; Trafton & Reiser, 1993). Worked examples are effective because learners view worked examples as a primary source of learning material (Lieberman, 1986; Pirolli, 1991; Segal & Ahmad, 1993). Some disadvantages to using worked examples are a lack of training with learner problem solving tasks, and stereotyping of solution patterns may be reasons to include other forms of instructional procedures such as completion problems (Sweller, van Merrienboer, Paas, 1998). The worked example effect directly applies to the instructor-created elaborations that are a completed example from the primary source of the instructor.

Assessment of cognitive load. Many types of cognitive load measurements exist with varying features. The main types of measurements may be task based, psychophysiological or subjective (Paas, van Merrienboer, Adam, 1994). The subjective measure utilizes a survey where the learner self-reports perceived cognitive load. Objective measurements such as a dual task performance utilizes a secondary task such as pressing the space bar when a prompt appears while interacting with the learning material and response time to the secondary task is measured. Other objective physiological measures may be used such as eye tracking, heart rate monitoring or electroencephalography. Many questions still exist regarding the sensitivity and reliability of each type of measurement (Paas, Van Merrienboer, Adam, 1994; Leppink, Paas, van Gog, van der Vleuten, van Merrienboer, 2013). Many researchers have used subjective measurements to test instructional procedures. A 9-point mental effort scale (Paas & vanMerrienboer, 1994; Paas, Tuovinen, Tabbers, Van Gerven, 2003) has been used extensively and is valid measurement of overall cognitive load (Leppink, Paas, der Vleuten, Van Gog, & Van Merriënboer, 2013). Ayres, (2006) used rating scales for intrinsic load while others used rating scales for intrinsic, extraneous and germane load separately (Eysink, de Jong, Berthold, Kolloffel, Opfermann, & Wouters, 2009). All instruments used varying scales, numbers of categories and labels. One main issue with measurement is the expertise reversal effect (Kalyuga, Ayres, Chandler, & Sweller, 2003) where the same instructional feature associated by one learner with germane load (enhancing learning outcomes) may be associated with extraneous load (hindering learning outcomes) by another learner depending on the level of the learner. A new instrument developed by Leppink, Paas, der Vleuten, Van Gog, & Van Merriënboer, (2013) contains a ten-item instrument for measuring the three types of cognitive load (intrinsic, extrinsic, and germane) on a 0-10 point scale. The Leppink, et al. (2013) study contained a relatively small sample size (n=58) and appears to be a promising measure, but a modified NASA TLX survey was chosen because it has been used in over 500 studies and was developed by the Human Performance Group at NASA.

Self-explanation effect. Self-explanation can improve learning by encouraging learners to generate explanations (Bielaczyc, Pirolli & Brown, 1995; McNamara, 2004; Renkl, 1997). According to Clark, Nguyen & Sweller, (2006 p 190) self-explanation is a mental dialog that the learner has when studying worked examples that helps the learner develop schema. More knowledgeable learners who have the resources to self-explain will benefit from the process. Novice learners may not have the resources available for the organizing and linking principle to function (Sweller, 2011). Self-explaining enhanced knowledge acquisition for eighth grade learners studying the circulatory system (Chi, De Leeuw, Chiu & Lavancher, 1994). Spontaneous self-explanations do not always come easily (Renkle, 1997) and eliciting self-explanations improves learning outcomes and learners with low prior knowledge received more benefit from elicitation (Renkle, Stark, Gruber & Mandl, 1998). Prompting learners in computer environments to self-explain each step of a probability problem (Atkinson, Renkl & Merill, 2003) improved performance. Self-explanations can be successfully used with worked examples (Sweller, 2011) given the learners have sufficient resources to self-explain. Eliciting self-explanations helps learners with low prior knowledge. These learners are in jeopardy of not having sufficient resources for germane processing (Sweller, 2011) and training with elaborations improves learning outcomes (Johnsey, et al. 1992). Studying or creating examples may require more cognitive resources from the learner than answering adjunct questions. If the process of elaboration creation imposes a greater expenditure of cognitive resources on the learner, the increase in essential processing may exceed available cognitive resources. When considering cognitive load, adjunct questions may be a better choice than elaborations to use with instructional video.

The research on using questions in instructional film and learner participation is conclusive in that learner participation during a film will increase learning under most instructional conditions (Allen, 1957). Allen (1957) defines the conditions for participation as the overt activity consciously engaged in by the learner. In particular, participation in the Yale Motion Picture Project Study (May & Lumsdaine,1958) involving questions inserted into an instructional film on the heart and circulatory system and found that the use of questions in film was effective. Modern day studies involving interactivity show increase in learning outcomes and increase in learner satisfaction (Zhang, Zhou, Briggs, & Nunamaker, 2006). Specifically, in health professions education, a meta-analysis of 15 articles involving internet-based learning, interactivity in films improved learning outcomes (Cook, Levinson, Garside, Dupras, Erwin, & Montori, 2010). Application level adjunct questions may engage the learner but elaborations may fully engage the learner depending on the essential processing necessary to participate in elaborations (Andre, 1979; Grabowski, 2004; Rickards, 1979).

Elaborations are a form of worked example and learners who have sufficient resources for germane processing should benefit from self-explanation during elaborations (Sweller, Ayres, & Kalyuga, 2011). Previous research on elaborations did not consider the implications of cognitive load and this may explain the variance in results. While it is clear from the research that using elaborations with self-explanation is better than not, it is unclear whether the improvement from elaborations is a result of available resources for germane processing. Elaboration research is also unclear regarding the use of instructor-created elaborations or learner-created elaborations and no research has investigated cognitive load and learner performance with these variables. The research on adjunct questions revealed that the use of application level questions used periodically in text would be effective. What is unknown is whether the use of adjunct questions will fully engage the learners' germane resources while viewing asynchronous video. Will adjunct questions be just enough to effectively use their resources and not overload their available resources?

Purpose of Study

This study investigated methods to engage the learner using generative learning strategies in the delivery mode of one-way prerecorded video. Engaging the learner in any delivery mode by requiring active processing of information is of utmost importance (Grabowski 2004). Since 54% of title IV degree-granting postsecondary institutions offering any distance education courses used one-way prerecorded video in their instruction (USDE, 2007), there is a need to make video an interactive learning experience. Additionally, the Association of American Medical Colleges' (AAMC), division of Organization of Learner Representatives report that out of the 55 survey respondents, 46, or 84% of medical schools record their first and second year classes (AAMC, 2013). For medical education, the use of class recording alone does not improve learning outcomes for any of the first and second years of medical school courses (Franklin, Gibson, Samuel, Teeter, & Clarkson, 2011). To make prerecorded video an active learning experience, generative learning strategies were used to solidify the schema of the learner and improve learning outcomes. Medical student population are time-impoverished and stressed, and a natural solution to this problem is to seek out the most effective means of educating this population. First and second year medical learners consisting of 897 learners in 6 major medical schools cite the learning environment and level of support from faculty as the main reason for burnout (Dyrbye, Thomas, Harper, Massie, Power, Eacjer, Szydlo, Novotny, Sloan & Shanafelt, 2009). A majority of medical students are using prerecorded video in some form. Adding generative learning experiences to prerecorded video was one possible way to make pre-recorded video an active learning experience.

The purpose of this study was to investigate the effects of the generative strategies of instructor-created elaborations, learner-created elaborations and adjunct questions on learning outcomes in an asynchronous learning environment, using pre-recorded video. The literature suggests that the use of generative strategies will positively affect learning outcomes but is unclear regarding the optimal use of generative strategies to support learning of foundational medical science principles at the application level. It was hypothesized that groups using the strategies of instructor-created elaborations, learner-created elaborations or adjunct questions will perform higher than a video only/control group.

Research questions

The following research questions guided this study:

1. What is the effect of generative learning strategy (i.e., instructor-created elaborations, learner-created elaborations, adjunct questions, & video-only) on learning outcomes?
2. What is the effect of generative learning strategy (i.e., instructor-created elaborations, learner-created elaborations, adjunct questions, video-only) on cognitive load?
    1. What effect does the generative learning strategy have on elaboration quality?

The research questions were formulated to answer the gaps in the literature. The first gap identified is the lack of clear evidence for when instructor-created elaborations would be best used. The use of learner-created elaborations also had mixed results in the literature. It was thought that by adding a measure of cognitive load, differences in the overall and individual dimensions of cognitive load would shed light on the efficacy of using different types of generative learning strategies. Of particular interest was the difference in load imposed by using a more passive method of learning in instructor-created elaborations versus a more active learning method in learner-created elaborations. Would the use of a more active learning strategy impose too much cognitive load or actively engage the learner and increase learning outcomes? By examining learning outcomes in addition to cognitive load, it was hoped to answer these questions surrounding generative learning use.

The final issue investigated in this research was the effect of self-explanation on learner-created elaborations. Self-explanation alone appeared to increase learning outcomes in most studies, but there were no studies investigating the use of self-explanation with learner-created elaborations. Would requiring learners to use self-reflection during instructor-created elaboration use make the experience more engaging and subsequently produce a higher quality elaboration response? Would requiring learners to use self-reflection during learner-created elaboration produce a higher quality elaboration or would the experience unnecessarily increase cognitive load?

Overall, the combination of measuring learning outcomes and cognitive load will give a unique perspective on the use of generative learning strategies in medical education. The lack of research in generative learning along with cognitive load in the area of medical education leaves a gap in knowledge for designers looking to make medical education a more active learning type of experience. Given the known advantages of generative learning use and self-reflection use, there may be fruitful results from utilizing these strategies in medical education.

CHAPTER II

METHOD

Research Design

This study used a true experimental design approach to examine the research questions. Participants were randomly assigned to one of four generative learning strategy groups (learner-created elaborations, instructor-created elaborations, adjunct questions and video-only/control group). The independent variable used in the study was generative learning strategy operationalized as instructor-created elaborations, learner-created elaborations, adjunct questions treatments with a video-only/control group. The learner-created elaboration group created elaborations (or examples) of simplified medical cases after watching a video in anatomy. The instructor-created groups studied elaborations created by the subject matter expert after watching a video in anatomy. The adjunct question group answered application level questions after watching a video in anatomy. The video-only/control group watched a video in anatomy.

Participants in all four groups had access to pre-recorded anatomy supplemental videos. Normally, the supplemental videos are a portion of the course offered in a public web site developed by a subject matter expert (http://www.anatomyguy.com). For this study, the longer video was edited into segments and entered in Blackboard as a stand-alone video to control for the extraneous cognitive load that may be imposed by the complex interface of the supplemental video site. All learners were given training in how to access the videos (Appendix A). The topics were chosen because they occur later in the semester when students are settled into the first semester of medical school and the topics are in a single region of the body. There was little difference in element interactivity and difficulty of learning in this region of the body. No feedback was given to the learners on their performance in anatomy but feedback was given to learners creating elaborations and learners self-reflecting on the instructor-created elaboration regarding the quality of their elaborations. In keeping with the normal course testing protocol of the first year anatomy course, each lesson post-test had questions at both the knowledge and the application level. A timeline for implementation was followed (Appendix B).

Participants and Setting

Participants for this study included first year undergraduate medical students enrolled in their first semester anatomy course at an urban medical school in the Mid-Atlantic region. The course was delivered via a traditional lecture/laboratory format. The lectures were recorded in a previous year and were utilized for asynchronous recorded lectures instead of face-to-face lectures. The course also provided supplemental recorded lectures available to all learners. The number of medical students enrolled in a class is 150. The course was given in one section with one main course director and multiple instructors. In recent years, students matriculating at the medical school have had a mean GPA of 3.44 and a mean MCAT of 30. The entering class of 2015 had 55% male and 45% female learners while 22% of them were underrepresented minorities. Students holding graduate degrees typically made up 28% of the class (EVMS, 2015). Participation in this study was voluntary. Inclusion criteria for this study consisted of completion of all three module assignments, completion of a post-test after each module and a workload survey for each module. Exclusion criteria for this study consisted of learners who previously attended a medical school, or repeated the class. Participants enrolled in the study were offered an incentive of being entered into a drawing for an iPad mini with a protective case and several apps for medical education preloaded on the device. The approximate value of the incentives was 350 dollars.

Measures

Learning Outcomes

Instructor-created multiple-choice test questions measured learning outcomes in a post-test after each module. The learning outcomes were measured by the post-test score ranging from 0-100. Each of the module post-tests included15 knowledge level questions along with 5 application level questions (Krathwohl, 2002) (Appendix C). Questions with an item difficulty between .60 and 1 p value were accepted and utilized. The post-test measured the effects of generative strategies on learning outcomes after each of the three lessons. Reliability of the post-test instrument was assessed using a KR-20 reliability coefficient.

Cognitive Load

The modified NASA-TLX survey with four dimensions of effort, mental demand, performance, and frustration level, measured on a scale of 1-100, examined the effects on cognitive load for each of the experimental conditions after each module (Appendix D). The dimension of effort was measured with one question about how hard the participant had to work to understand the material. The dimension of mental demand was measured with two questions, first question asked about mental activity and second question asked about how demanding the learning was. The dimension of performance was measured with two questions, where the first question asked about how successful the learner was in understanding the content, the second question asked the learner how satisfied they were with their accomplishment. The dimension of frustration level was measured with one question asking the learner to rate their frustration from very low to very high. The NASA-TLX survey measured workload while studying elaborations provided by the instructor, creating elaborations, or answering application-level adjunct questions. The survey is a modified version of the NASA-TLX assessment tool (Hart & Staveland, 1988). The NASA-TLX is a subjective tool that allows users to rate their perceived level of mental demand on a continuous 100-point scale. The entire tool measures mental demand, physical demand, temporal demand, overall performance, frustration level, and effort. The section measuring mental demand was utilized for this study. The NASA-TLX instrument has been used in over 500 studies and was developed by the Human Performance Group at NASA. All learners answered questions regarding their cognitive load after each lesson. Cognitive load was measured in a survey based on Nathional Aeronautics and Space Administration’s Task Load Index (Hart & Staveland, 1988). The TLX is a result of years of research obtained from 16 experiments. The original instrument included measurements for cognitive tasks which were used in this research and measurements not used (manual control tasks, complex laboratory and supervisory control tasks, and aircraft simulation) due the the nature of the research. The results of the cognitive load questions were analyzed to determine if a relationship exists between perceived workload and post-test scores. The questions used for percieved workload were formatted as a continuous scale rating from 1-100. The selection of the NASA-TLX instrument was based on the desire to measure the three dimensions of cognitive load. The mental demand questions may measure intrinsic cognitive load, the frustration question may measure extraneous cognitive load, and the effort question may measure germane processes (Gerjets, Scheiter, & Catrambone, 2006).

Elaboration Quality. Quality of elaborations is a factor that only applied to the leaner-created elaborations group and the instructor-created group because the other two groups did not complete self-reflections. Participants in these groups (instructor-created and learner-created) had to complete a written response to the self-reflection questions for each part of the examples they either created or studied. Each question response was judged by the same rubric for both the learner created group and the instructor created group of elaborations. The instructor-created and learner-created elaboration groups generated responses to elaboration and self-reflection prompts in their treatment groups after each module. The quality of responses was measured with a four dimension, three-level rubric that was used to give feedback to the instructor-created and learner-created groups. The dimensions of case presentation, origin, insertion and action, imaging or tests, and differentials were measured at three levels. The measurements assessed quality at the levels of: does not meet expectation, meets expectation, or exceeds expectation. Each dimension was aligned with objectives, was discrete and is measureable (Appendix E). The rubric was used to give feedback to the learner on the quality of their responses in the learner-created and the instructor-created groups for each module.

Procedures

The independent variable of generative strategy was operationalized as the follows: instructor-created elaborations, learner-created elaborations, adjunct questions, and video-only. Learners were randomly assigned to one of the four generative learning strategies groups labeled instructor-created elaborations, learner-created elaborations, adjunct questions, and video-only.

Instructor-created elaborations

Learners attended regular classes and watched a supplemental instructional video in anatomy. To train learners to do self-reflections, instructions were provided for the learners to review before studying an instructor-created elaboration (Appendix F). Learners then studied instructor-created elaborations (Appendix F). These expert elaborations were created by the instructor to help learners get more information about a certain topic such as how origin, insertion, and action of a muscle could be affected by a condition. Learners were required to self-explain, in writing, why each part of the instructor examples were appropriate and submit their answers in a course management system (CMS). An example of excellent and poor answers to self-reflection questions was provided to learners in the beginning of each topic for training in how to study elaborations (Appendix F).

Learner-created elaborations

Learners attended regular classes and watched a supplemental instructional video in anatomy. To train learners to create elaborations and self-reflections, instructions were provided for the learners to study before creating their elaborations (Appendix G). Learners then created their own examples or elaborations about a certain topic such as how origin, insertion and action of a muscle could be affected by a condition using an outline to prompt for the required parts of the elaboration (Appendix H). Learners reflected on the parts of their examples as they created them to explain why they consider their answers to be a good example (Appendix I). The learner-created elaborations were submitted in the CMS. Feedback was given to the learners after each submission in the form of a rubric (Appendix E). The rubric was completed by a trained teaching assistant who had mastered the content in anatomy and returned to the learner before the next topic is presented.

Adjunct questions

Learners attended regular classes and watched a supplemental instructional video in anatomy. Questions were answered after every 10-15 minutes of video in a natural break on the topic (Appendix J). Questions were presented to learners in the CMS, learners were encouraged to go back and review the video to write down the answers to the questions. Answers were presented to and collected from the learner in test management software.

Video Only

Learners attend regular classes and watched a supplemental instructional video in anatomy. Learners were also prompted to watch a recording of the regular lecture given in class to control for time on task.

The dependent variables were the learning outcomes, and the perceived workload. Learner outcomes were measured with a multiple-choice 20-question knowledge level and application level post-test after each topic. The test questions were created by the instructor and verified to be at the knowledge and application levels by a panel of curriculum experts at the institution. The perceived workload was measured with a survey at the end of each lesson completed to allow learners to rate their perceived workload on a continuous scale of 0-100 with a series of questions about effort, mental demand, performance, and frustration level (Hart & Staveland, 1988). Perceived workload was measured in a survey (Appendix D) based on National Aeronautics and Space Administration's Task Load Index (NASA-TLX; Hart & Staveland, 1988).

The learning outcomes were measured by post-test scores on an assessment created by the instructor and approved by a panel of subject matter experts and education experts in the office of medical education. Questions (Appendix C) were judged for measurement of the stated objectives (Appendix K). The post-test, given at the end of each of the three lessons, measured learning outcomes at the knowledge and application levels of learning. The panel approving the test questions consisted of two instructional designers and two subject matter experts. Each lesson was tested with a multiple-choice test after each lesson and analyzed individually. An applied cognitive task analysis was employed with the help of subject matter experts (Milletelo & Hutton, 1998) and was performed before designing the content for this study (Appendix L).

Data Analysis

For research Question 1, an analysis of variance (ANOVA) was used to test the differences in learning outcomes across the generative learning strategy groups of instructor-created elaborations, learner-created elaborations, adjunct questions as well as the video-only control for each quiz.

For research Question 2, a repeated measures ANOVA was used to answer the second research question to measure the effect of generative learning strategy on perceived workload.

For research Question 3, a repeated measures ANOVA was used to measure the differences in quality of elaboration use.

Question		Data	Scores	Analysis
1	What is the effect of generative learning strategy on learning outcomes?	Post-test scores for each of the three topics assessed.	0-100	ANOVA used to measure differences in learning outcomes for each quiz.
2	What is the effect of generative learning strategy on cognitive load?	Survey data of learner perception of cognitive load for each of the topics addressed	0-100	Repeated measures ANOVA used to measure the differences in reported perceived workload.
3	What effect does the generative learning strategy have on elaboration quality?	Rubric scores from instructor-created and learner-created elaborations for each of the topics addressed	0-100	Repeated measures ANOVA used to measure the differences in elaboration quality.

CHAPTER III
RESULTS

In the statistical analyses below, a significance level of .05 was used and measures of effect size are reported with partial eta squared.

Analysis of Learning Outcomes

Learning outcomes were analyzed by four groups to evaluate the differences between adjunct questions, learner-created examples, instructor-created examples, and video only treatment groups. Table 1 represents the means and standard deviations of learning outcomes for the four groups.

Table 1
Means and standard deviations of learning outcomes by treatment group

Quiz (Trial)		1		2		3	
Group	n	M	SD	M	SD	M	SD
Adjunct Questions	13	60.39	15.06	61.54	17.96	67.69	21.18
Learner-created Examples	5	63.00	16.05	56.00	17.10	66.00	13.42
Instructor-created Examples	8	63.75	14.58	68.75	8.35	59.38	16.35
Video Only	7	59.29	7.87	59.27	10.58	62.86	22.33

Note: Scores range from 0-100 for all items

The results of the analysis revealed no significant difference in test performance. An analyses of variance (ANOVA) was performed for quiz 1. No significant differences were between groups on learning outcomes, $F(3,29) = .295$, $p = .829$, $\eta^2 = .03$. An ANOVA was performed for quiz 2. No significant differences were between groups on learning outcomes, $F(3,29) = .852$, $p = .477$, $\eta^2 = .08$. An ANOVA was performed for quiz 3. No significant differences were found between the four groups on learning outcomes, $F(3,29) = .224$, $p = .879$, $\eta^2 = .02$.

Analysis of Cognitive Load

For all trials, participants in the create examples group had the highest mean of all groups while the participants in the video only group had the lowest mean for all trials. Table 2 represents the means and standard deviations of total cognitive load for the four groups by trial.

Table 2
Means and standard deviations of total cognitive load by four treatment groups

Total Load Measurement (Trial)		1		2		3	
Group	n	M	SD	M	SD	M	SD
Adjunct Questions	13	56.66	12.31	53.56	14.45	55.12	10.67
Learner-Created Examples	5	58.33	11.16	65.50	16.58	64.33	15.39
Instructor-Created Examples	8	53.40	10.47	51.35	10.86	55.31	9.28
Video Only	7	45.11	10.91	43.10	13.34	43.69	15.67

Note: Scores range from 0-100 for all items

Participants in the learner-created examples group reported the highest levels of overall mental effort in Trial 1 (M=58.33, SD = 11.16), followed by adjunct question (M=56.66, SD = 12.31), and followed by instructor-created examples group (M=53.40, SD = 10.47). Participants in the video only group reported the lowest overall mental effort (M = 45.11, SD = 10.91).

Participants in the learner-created examples group reported the highest levels of overall mental effort in Trial 2 (M=65.50, SD = 16.58), followed by adjunct question (M=53.56, SD = 14.45), and followed by instructor-created examples group (M=51.31, SD = 10.86). Participants in the video only group reported the lowest overall mental effort (M = 43.10, SD = 13.34). Participants in the learner-created examples group reported the highest levels of overall mental effort in Trial 3 (M=64.33, SD = 15.39), followed by instructor-created examples group (M=55.31, SD = 9.28) followed by adjunct question (M=55.12 SD = 10.67), and participants in the video only group reported the lowest overall mental effort (M = 43.69, SD = 15.67).

Total cognitive load measures were analyzed by four groups to evaluate the differences between adjunct questions, learner-created example, instructor-created example, and video only treatment groups. The results of the analysis revealed no significant difference in cognitive load. A repeated analyses of variance (ANOVA) was performed. No significant differences were found between the four groups on total cognitive load, $F(3,29) = 2.10$, $p = .122$, $\eta^2 = .22$.

Table 3 shows the means and standard deviations by dimension of demand in cognitive load by trial. A repeated measures ANOVA was used to measure the differences in total demand by groups. The results show no significant differences in the dimensions of demand by the four groups of adjunct questions, learner examples, instructor examples and video only $F(3,29) = 2.79$, $p = .058$, $\eta^2 = .22$.

Table 3

Means and standard deviations of demand dimension of cognitive load by treatment group

Trial		1		2		3	
Group	n	M	SD	M	SD	M	SD
Adjunct Questions	13	60.19	18.10	58.85	18.14	55.77	18.04
Learner-created Examples	5	65.50	15.45	70.00	20.92	68.00	17.17
Instructor-created Examples	8	54.36	23.05	49.06	12.95	55.31	16.50
Video Only	7	48.93	22.82	40.00	18.92	35.00	20.32

Note: Scores range from 0-100 for all items

Table 4 shows the means and standard deviations by dimension of effort in cognitive load by trial. A repeated measures ANOVA was used to measure the differences in total effort by groups. The results show no significant differences in the dimensions of effort by the four groups of adjunct questions, learner-created examples, instructor-created examples and video only $F(3,29) = 0.889$, $p = .458$, $\eta^2 = .084$.

Table 4

Means and standard deviations of effort of cognitive load by treatment group

Trial		1		2		3	
Group	n	M	SD	M	SD	M	SD
Adjunct Questions	13	54.23	26.83	46.92	23.76	51.54	22.86
Learner-created Examples	5	52.50	23.63	62.50	28.72	50.00	23.09
Instructor-created Examples	8	46.44	18.80	49.44	29.00	58.89	22.61
Video Only	7	38.57	21.16	35.71	19.88	37.14	30.94

Note: Scores range from 0-100 for all items

Table 5 shows the means and standard deviations by dimension of frustration in cognitive load by trial. A repeated measures ANOVA was used to measure the differences in total frustration by groups. The results show no significant differences in the dimensions of frustration by the four groups of adjunct questions, learner-created examples, instructor-created examples and video only $F(3,29) = 0.475$, $p = .702$, $\eta^2 = .047$.

Table 5

Means and standard deviations of dimension of frustration of cognitive load by treatment group

Trial		1		2		3	
Group	n	M	SD	M	SD	M	SD
Adjunct Questions	13	41.92	30.86	44.62	30.71	36.15	30.14
Learner-created Examples	5	36.00	24.03	40.00	33.91	44.00	37.81
Instructor-created Examples	8	53.75	35.43	43.13	26.58	56.25	32.92
Video Only	7	38.57	28.97	30.00	21.60	34.29	28.20

Note: Scores range from 0-100 for all items

Analysis of Elaboration Quality

The quality of elaboration was measured with a rubric. The means for the two groups, study instructor-created and learner-created groups are presented in Table 6

Table 6

Means and standard deviations of rubric grades by examples treatment group

Quiz (Trial)		1		2		3	
Group	n	M	SD	M	SD	M	SD
Learner-created Examples	5	73.00	10.37	79.00	6.52	77.00	4.47
Instructor-created Examples	8	82.50	16.69	88.13	13.08	89.37	14.00

Note: Scores range from 0-100 for all items

Means for the study examples were consistently higher than the learner-created examples group for case grades for each trial. A repeated analyses of variance (ANOVA) was performed to examine the differences between the two groups of study instructor-created examples and learner-created examples group on the case grades for each group. No significant difference was found between groups on case grades, $F(2,10) = 1.268$, $p = .323$, $\eta^2 = .06$.

CHAPTER IV

DISCUSSION

This study examined the effect of generative strategies on learner outcomes and dimensions of cognitive load while utilizing recorded video instruction in an online learning environment. Results of this study provided no support for the hypothesis of engaging learners in generative strategies would improve learning outcomes. Participants who utilized generative learning strategies had no difference in learning outcomes as compared to participants who did not utilize generative learning strategies. These results do not support the Wittrock's (1974, 1990, 1991, 1992) theory of generative processing regarding the engagement of generative strategies to prompt learners in making new connections between prior and new knowledge. The results do not support the research results of Stein & Bransford (1979), DiVesta & Peverley (1984), and Johnsey, Morrison & Ross (1992) that utilizing elaborations would positively affect learning outcomes. One potential reason may be the type of learners who participated in these studies. The three previously mentioned studies involved undergraduate learners or adult learners utilizing elaborations as a generative learning strategy and this population may be very different from medical student learners.

Medical students may be very different in terms of knowledge and motivation than undergraduate learners who participated in the previously cited studies. Post baccalaureate students like medical students are high achieving students that may have superior skills in choosing learning strategies. Medical students have had much practice learning science material as evidenced by their good grade point averages, and higher than average Medical College Admission Test (MCAT) scores. The MCAT measures science knowledge, critical analysis and reasoning skills (AAMC, 2016). The national averages for 2015 admission to medical school is a GPA of 3.55 and an MCAT of 28.3 (AAMC, 2015). Learners in the cohorts participating in the study had an average GPA of 3.4 and MCAT score of 30. The above average MCAT score of 30 may be an indication of the advanced nature of the learners.

The results do not support the hypothesis that utilizing application level adjunct questions during an online video presentation would increase learning outcomes (Andre, 1979; Rickards & Denner, 1978; Rickards, 1979). Other studies utilizing a medical school population, found no differences in learning outcomes. Students creating flashcard style questions in medical school showed a non-significant improvement in learning outcomes in a study by Bow, Dattilo, Jonas & Lehmann, (2013) but less than half of students in the Bow et al. study self-selected to participate in creating materials instead of randomly assignment to a strategy. In the aforementioned study, an increase in learning outcomes did not occur at a significant level, and students who were skilled in question creation may have been the ones to self-select to participate. Bow et al. also did not measure cognitive load to see whether self-selection of strategy use impacted cognitive load. Another medical education study (Mclaughlin et al., 2014) found a significant difference in learning outcomes using generative strategies, but students had the choice to work in pairs to answer questions in a flipped learning environment. The synergy of pairing in answering questions could have made the difference in increasing learning outcomes.

The lack of connection between strategy use, cognitive load and learning outcomes is present in the literature and may not be understood completely. The conflicting results regarding elaboration use on learning outcomes show the need for more research on the topic. The addition of a cognitive load measurement may shed light on the impact to intrinsic cognitive load especially for the populations of undergraduate medical learners. Examining the measure of cognitive load may help define the effect that level of learner has on intrinsic cognitive load. The level of learner may help determine optimum strategy use. More research may be needed to investigate this possible connection.

Additionally, results of this study do not support Chi, et al. (1994) argument that self-reflection is superior to only interacting with instructional materials, specifically, self-reflection during the use of elaborations. One possible reason for this may lie in the knowledge and motivation of learners participating in this study. The higher knowledge and higher motivation of the learners participating may occlude any benefits of self-reflection because the learners are already engaged and motivated to learn the material. Multiple studies (Bielaczyc, Pirolli & Brown, 1995; McNamara, 2004; Renkl, 1997) found benefits of self-explanation in many contexts but all learners had low prior knowledge. Chi et al. (1994) found that eighth grade learners studying the circulatory system benefitted from self-explanation but the population in this study are post-baccalaureate medical students with extensive prior knowledge of science.

One explanation from the literature is that low prior knowledge learners have fewer prior knowledge connections to make with new knowledge and the self-explanation prompts provide opportunity for learners to make new connections (Renkle, 1997; Renkle, Stark Gruber, & Mandl (1998). Additionally, Renkle, et al. (1998) found that learners with low prior knowledge received more benefit from elicitation. The learners in this current anatomy study were all medical students with a high prior knowledge in science, given the requirements for admission of 3.45 average science GPA (AAMC, 2015) required courses in biology, chemistry, physics and organic chemistry with biochemistry highly recommended for this population.

The characteristics of a typical medical student may yield some additional explanation about the learning outcomes and cognitive load outcomes in this study. Medical students are generally highly motivated, have high prior knowledge in science, are time-impoverished and may have developed their own preferences for use of generative strategies (Nair, Shah, Seth, Pandit & Shah, 2013; Kusurkar, Croiset, Galindo-Garré & Ten Cate, 2013). The average number of hours medical students spend in class or studying is 10 hours per day (AAMC Y2Q, 2016), and have a high level of stress as measured by the Perceived Stress Scale, (AAMC Y2Q, 2016).

The addition of generative strategies did not affect learning outcomes in any generative group and an investigation of cognitive load may yield an explanation for these findings. The original research question investigated the difference in cognitive load for four groups of instructor-created examples, learner-created examples, adjunct questions and video only. To further investigate cognitive load measures and the effect generative strategies have on cognitive load, a post-hoc analysis was performed.

Data were analyzed by learners using generative strategies vs. non-generative strategies by combining all generative strategy treatment groups against the video only (control) group. An ANOVA was performed. A significant difference was found between groups on total cognitive load, $F(1,31) = .609$, $p = .019$, $\eta^2 = .16$. The results of the analysis revealed a significant difference in total cognitive load. An ANOVA was performed to analyze differences in the 3 dimensions of cognitive load as measured by the NASA-TLX. The three dimensions are demand, effort and frustration. Cognitive load measures were significantly different between two-groups on the dimension of demand, $F(1,31) = 5.79$, $p = .022$, $\eta^2=.157$. No significant difference was found on the dimensions of effort or frustration.

Cognitive load measures were affected by the use of generative strategies in this study. The measurement of overall cognitive load from the NASA-TLX was affected by the use of generative learning strategies. The specific measurement of demand was also affected by generative strategies at a significant level but no other dimension of cognitive load was significantly affected. The overall cognitive load measure is parsed out with six questions to measure the areas of demand, effort and frustration. Specifically, the measurement of demand was significantly affected by the use of generative learning strategies. The measure of demand may be a measurement of intrinsic cognitive load as proposed by Gerjets et al. (2006). The demand measure increased without providing the benefit of increased learning outcomes. One reason for this could be that the layering of any prescribed strategy on top of the learning material may be unnecessarily increasing the demand, or intrinsic cognitive load. These results point to an increase in intrinsic cognitive load from the use of generative learning strategies. Leppink, et al., (2013) reported that the measures of intrinsic load and germane load may not be linear. If a learning task is easy, the explanation and instructions for the task may not contribute to learning. Leppink, et al., (2013) argue that if the learning experience was too complex for a learner, germane load capacity may be limited. More research may be needed to clarify the measures of intrinsic load and germane load.

In this study, cognitive load was reported in the moderate range from 45 to 58 on a 100 point scale so the task may not have been difficult enough even though it was significantly different for the learners using generative learning strategies. Specifically, an increase in cognitive load was measured in the dimension of demand that significantly increased for the group of learners using generative strategies. While learning outcomes were not negatively affected, the outcomes were also not positively affected by the use of generative strategies and may be because the subject of anatomy is both verbal and spatial in nature. In this study, the addition of generative learning strategies did not benefit the learner. The addition of generative learning strategies increased intrinsic load for students and consumed resources that would otherwise be available for germane processing. One explanation for this finding may lie in Fiorella & Mayer's, (2015) recommendation to use verbal strategies (summarizing, self and explanation) for non-complex or non-spatial material and spatial generative strategies (mapping, drawing) for teaching complex spatial concepts. The discipline of anatomy has both verbal and spatial components and may benefit from using spatial generative strategies such as creating flashcards.

The task of self-explanation and generation of examples was thought to decrease in difficulty with practice. The overall mental effort was not significantly different in Trials 1 and 2 but significantly differed in Trial 3. The mean cognitive load increased in the generative group for Trial 3, thus not supporting the idea that elaboration over repeated measures decreases in difficulty and may decrease cognitive load. A repeated measure using the elaboration (examples) may not be necessary for this population, especially creating elaborations in the form of cases because the majority of instruction in medical school is in the form of cases. The dimension of demand was significant in Trial 3 for learners using generative strategies. The level of overall mental effort significantly increased in Trial 3 and did not decrease as expected. An explanation for overall cognitive load not decreasing as the trials advanced, for the study examples group and create examples group, may be found in the finding that the generative strategies only increased the demand dimension of cognitive load and perhaps did not make more germane resources available for processing the learning material

The dimension of effort as a subscale of cognitive load measure was found to relate to germane processing by Gerjets et al. (2006). Higher means of effort were reported by learners in the generative learning group compared to the video only group but no significant differences were found in any trial. Learners were attending to instructional material due to the higher reported mean, and germane processing was occurring, but not at a significantly different level in any trial. The increase of germane processing is desirable as long as resources are available for processing the learning material. In this study, the generative strategies were engaging enough to show an increase in the mean of effort in all generative categories over the video only group, but not enough to reach statistical significance. The learning outcome means were higher in the generative groups, but not significantly higher. The learning outcome means were overall lower than expected for all groups. The learning material may not have been engaging enough to bring overall cognitive load to an optimal level. The relationship between intrinsic load and germane load may not be linear (Leppink, 2013) because one learner may have low prior knowledge and interpret the task as demand, while another student may have high prior knowledge and interpret the task as effort. The relationship between prior knowledge and cognitive load may need some further research.

Typically, similar examinations in anatomy courses have a higher mean around 80%. One explanation for the higher mean with the regular assessments in anatomy could be the extensive laboratory experience that accompanies lecture. In this study, the instruction was all delivered with video and no opportunity to complete an actual laboratory. Although the video was a virtual dissection and review of the region, and the generative treatments were meant to increase attention directed to germane resources and processing, the treatments seemed only to increase intrinsic cognitive load and divert resources from potential germane processing. An examination of the measure of frustration on the NASA-TLX may yield some additional insight in terms of learning new concepts.

The NASA-TLX measure of the dimension of frustration was found to relate to extraneous cognitive load (Gerjets, 2006) and in this study was not found to be statistically different for any group. The means for frustration in the generative group was consistently lower in all three trials, but not at a level of significance. Adding generative strategies did not increase frustration for learners in the generative strategy group, but not significantly and not enough to impact learning outcomes. An explanation for this finding may be that adding generative strategies for medical students will slightly increase frustration and possible extraneous cognitive load by requiring a strategy in addition to one the student typically prefers to use.

Quality of elaboration was examined to determine if the higher quality answers were related to those with higher measures of learning outcomes. There was no relationship between the two groups of study instructor-created examples (SE) and student-created examples (CE) group on the case grades for each group. One possible reason for this may lie in the type of learner that is highly motivated, higher previous science knowledge, and the nature of anatomy as both verbal and spatial in nature. The strategy of examples may not be the best strategy to use for learning anatomy and therefore may not provide any benefit to learning outcomes.

The quality of case grades did not improve over the course of three trials. The literature shows varying results regarding the utility of creating examples vs. studying examples. Instructor-created examples worked to improve improved learning for some cases including generated syntax examples but did not improve conceptual learning (Reder, Charney & Morgan, 1986). Stein and Bransford (1979) showed that focusing the instructor-created elaborations on the objectives were helpful in the retention of verbal information. Instructor-created elaborations have been shown to facilitate learning under specialized conditions such as high prior knowledge (Rothkopf & Billington, 1974). In this case, the learners did not demonstrate higher learning outcomes, but did report a higher intrinsic cognitive load from the treatment. This may be due to the learner interpreting the task as demand. The same type of varying results occurs in the literature regarding learner-created examples. Johnsey, Morrison & Ross, (1992) found no difference between learner-created elaborations and instructor-created elaborations while Mayer's (1980) research found both to be effective in helping learners apply concepts and solve problems.

Limitations to Study

A limitation of the study was a relatively small number of participants (n=33). Participant recruitment was hindered by the time required to participate in a repeated measures study requiring 2-3 hours of time outside of the regular curriculum time. The required curriculum time is an average of 24 hours per week, with the additional study hours on top of the required hours, not leaving much extra time to participate in this study. Incoming students have a varied background in anatomy depending on their undergraduate program. The anatomy guy supplemental videos are a source for learners to fill in knowledge gaps including practice test questions. One unanswered question that emerged from the study is the effect that the level of learner has on the measure of intrinsic cognitive load. An analysis of prior experience in anatomy from student transcripts in addition to overall science grade point average and MCAT admissions scores may reveal a relationship between prior knowledge and perception of cognitive load. The quality of cases did not improve over the course of three trials and one reason for this could be the familiarity that medical students already have with case creation (examples), during the course of their first semester, multiple courses, including a clinical course on doctoring, used cases in a standard format for instruction.

Another limitation to the study lies in the subjectivity of the measurement instrument for cognitive load. The NASA-TLX was chosen because it had been used in over 500 students, but a new tool, Leppink, et al (2013), shows promise as a new measure for future studies.

Future Research

Future research for the area of strategy use based on learner pre-requisite knowledge holds great promise for medical education. The attributes for learners in medical education provide a rich environment for studying strategy use for a population of learners who are highly motivated, have high abilities, and have high previous knowledge. More learner analysis is needed in future research to analyze the qualities of medical school learners that make this population unique. Performance results from previous science undergraduate courses, specifically performance in a directly related subject such as anatomy would have been useful for this study. The learner analysis may give insight for strategy use as pre-requisite knowledge may relate to how learners are applying knowledge and using strategies.

For years, designers were told that manipulation of intrinsic load was only possible by sequencing material and not possibly by adding strategies to the learning experience. In this study, adding strategies appeared to increase intrinsic cognitive load and future research is needed to investigate why this might happen for the population of leaners in medical education.

For future research, using a new measurement tool may give insight into the increase in intrinsic load for high knowledge populations. Additionally, future research may provide a more in-depth examination into the process of studying examples or creating examples that could reveal more information about the relationship between the effects of generative strategies and cognitive load using a mixed method think-aloud protocol. Additionally, a survey about preferred generative strategy use may yield insight into the issue of prescribing a strategy contrary to a preferred strategy that may increase intrinsic cognitive load. The think-aloud protocol may also yield insight into the issue of cognitive load while studying or creating examples. The learners with high prior knowledge may be able to articulate the perception of working against their preferred generative learning strategy. For example, if a learner prefers to use concept maps and is required to use a creating example strategy, the learner may be able to articulate the increase in perception of demand or intrinsic load. Having the learner work through the material and articulate through the think aloud process may shed a great deal of light on the issue of cognitive load because the measure is a perception. Digging into the perception for details of why learners perceive material to be more demanding and may reveal valuable information. Additional information about the actual relationship between the categories of the NASA-TLX and the category of intrinsic cognitive load may need to be gathered. The Gerjets (2006) study where the categories of the TLX and cognitive load were equated used undergraduate learners from various programs. There may be a difference in perception of intrinsic load by medical students that varies from the perception of intrinsic load for undergraduate learners. One way to measure this may be to have both undergraduate anatomy students at another university participate in the same treatment and compare their work aloud perceptions to the work aloud perceptions of admitted medical students.

The high prior knowledge in science areas, learner-type admitted to medical school may enter the program with successful strategies already in place such as utilizing flash cards, concept maps, mnemonics, or drawings to learn anatomy material. An extension of this study could analyze the relationship between choice of strategies and learning outcomes. For example, analyzing learning outcomes and cognitive load for learners who choose to use pre-made flash cards v learners who choose to create their own flash cards rather than randomly assigning learners to strategies. Will the level of learner affect the choice of strategy? Will the use of strategy then affect learning outcomes? An analysis of strategy choice with cognitive load perception may reveal a higher level of metacognitive awareness within the population of medical students.

A survey of learners who participated in this study may reveal interesting information for preference of generative strategies relating to learning outcomes and cognitive load. Students who preferred to answer questions but had been randomly assigned to the create example group may give insight to the issue of increasing intrinsic load by prescribing a generative strategy other than the preferred strategy. Future research could examine the specific issue of instructor created examples versus learner created examples in a study that would have more power using only two groups.

Conclusion

A conclusion to be drawn from these results would be that the imposed cognitive load from the treatment may not be worth the increase in cognitive load in terms of learning outcomes. The type of generative strategy may not be appropriate for this subject area. For example, answering questions alone, may not engage learners enough to affect learning outcomes. More research is necessary to parse out the effect that prescribing a generative strategy to a higher knowledge population such as medical students would have on learning outcomes. Using a work aloud protocol may also reveal a difference of perception of demand among different populations of learners. Because the measure of cognitive load using the NASA-TLX or any similar survey measure is subjective, there may be differences in perception based on the type of learner.

This research has attempted to provide insight into the use of generative strategies for use with recorded presentations in an authentic medical anatomy classroom environment. Given the results of no significant impact to learning outcomes, and the significant increase in the demand measure of intrinsic cognitive load, these results may give the foundation to future research.

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Appendix A

Training for Accessing Recorded Lecture Videos

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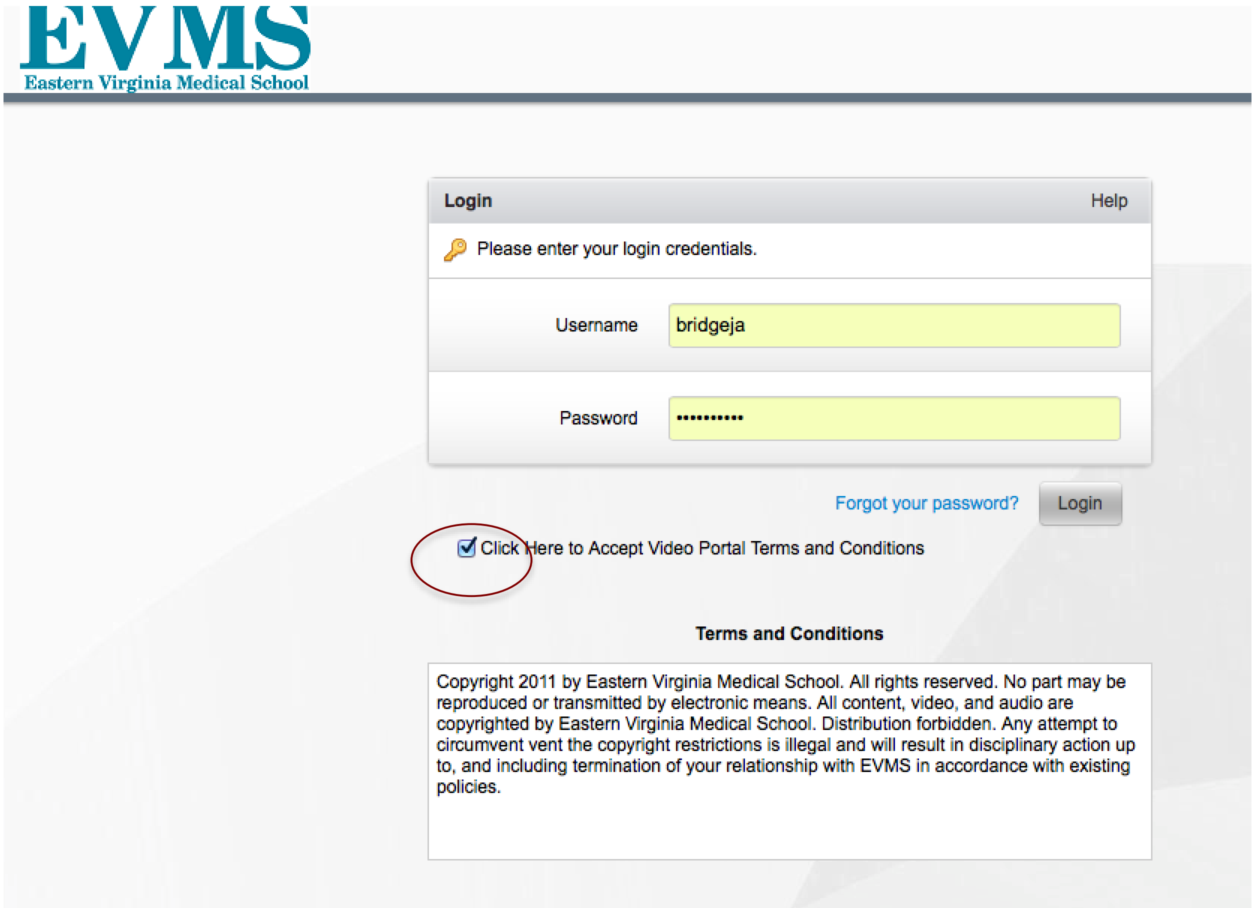

Appendix B
Timeline
Order of Operations

Early 2015 – Recruit volunteer subjects, randomly assign to 4 groups (Instructor-created, Learner-created, Adjunct Questions, and Video Only/control)

Mid-Spring 2015
1. First module instruction- all groups watch instructional video
    a. Participate in treatment group (Instructor-created, Learner-created, Adjunct Questions, and Video Only/control)
    b. Instructor-created and Learner-created groups are given rubric as feedback for quality of responses
    c. Posttest for all groups
    d. Workload survey for all groups
2. Second module instruction- all groups watch instructional video
    a. Participate in treatment group (Instructor-created, Learner-created, Adjunct Questions, and Video Only/control)
    b. Instructor-created and Learner-created groups are given rubric as feedback for quality of responses
    c. Posttest for all groups
    d. Workload survey for all groups
3. Third module instruction- all groups watch instructional video
    a. Participate in treatment group (Instructor-created, Learner-created, Adjunct Questions, and Video Only/control)
    b. Instructor-created and Learner-created groups are given rubric as feedback for quality of responses
    c. Posttest for all groups
    d. Workload survey for all groups

Release all treatments to all learners

Appendix C
Test Questions

Gluteal Posterior Topic 1

2. Which muscle in the gluteal region both extends the hip and performs lateral rotation?

A) Gluteus minimus
B) Piriformis
C) Gluteus medius
D) Gluteus maximus *

3. The majority of gluteus maximus muscle distally attaches to which structure?

A) Gluteal line on the femur
B) Dorsal sacrum
C) IT band*
D) Sacrotuberous ligament

4. The obturator internus tendon separates which structures?

A) Superior and inferior gemelli*
B) Piriformis and superior gemellus
C) Obturator externus and internus
D) Gluteus minimus and medius

5. Which of the muscles below is the most superficial?

A) Gluteus medius
B) Gluteus minimus
C) Tensor fascia lata*
D) Piriformis

6. Which muscle(s) would be compromised if there were pain with hip extension only in the position with the knee extended?

A) Hamstrings*
B) Gluteus maximus
C) Gluteus minimus
D) Semitendinosis

6. Which muscle is the only gluteal muscle that originates from the posterior/dorsal surface of the sacrum?

A) Piriformis
B) Biceps femoris
C) Gluteus medius

D) Gluteus maximus*

7. Which muscle DOES NOT laterally rotate the hip?

A) Gluteus minimus*
B) Obturator externus
C) Gluteus maximus
D) Obturator internus
E) Piriformis

8. Which muscle DOES NOT medially rotate the hip?

A) Biceps femoris*
B) Semimembranosus
C) Semitendinosus
D) Gracilis

9. The biceps femoris muscle

A) Is medial to the popliteal fossa
B) Performs knee flexion
C) Performs knee extension
D) Is lateral to the popliteal fossa
E) Both C and D*

10. Which is true of gluteus maximus?

A) It's distal attachment is only on the femur
B) It's proximal attachment is only on the on the ischium
C) It performs medial rotation with the other gluteals
D) It flexes the hip
E) None of the above*

11. Which is true of the tensor fascia lata?

A) It can be a common problem in runners when tight
B) Its proximal attachment is only on the ASIS
C) Its only action is hip abduction
D) It is a hip extensor
E) Both A and B*

12. Which muscles distally attach to the greater trochanter?

A) Gluteus maximus
B) Quadratus femoris
C) Tensor fascia lata
D) Piriformis

E) Both A and D*

13. Apart from the three gluteal muscles and the tensor fascia lata, all of the lateral rotators are inferior to which muscle?

A) Piriformis*
B) Obturator externus
C) Superior gemellus
D) Quadratus femoris

14. The most powerful extensor of the hip is which muscle?

A) Psoas major
B) Iliacus
C) Gluteus maximus*
D) Obturator externus
E) None of these

15. If a patient stands on one leg, the femur has a tendency to drop. Which muscle prevents this?

A) Gluteus maximus
B) Piriformis
C) Gluteus medius*
D) Iliacus

16. A 20-year old football player is complaining of severe pain after performing straight leg deadlifts (going from trunk/hip flexion to extension). His pain is located superior to the knee joint on the posterior/lateral aspect of the thigh. Upon examination you notice weakness and pain during knee flexion during hip external rotation. The muscle most likely affected is:

A) The semi-tendinosis because it performs knee flexion and is less vascularized more distally and more likely to get injured
B) The biceps femoris because it performs knee flexion and inserts on the lateral aspect of the leg*
C) The semimembranosus because it flexes the knee and has a large muscle belly
D) The tensor fascia lata because it runs along the lateral aspect of the knee where there is pain

17. A 78-year old female patient has been on bed rest for the past few weeks from chemotherapy treatment. She is now feeling better after her last round of chemotherapy and it is recommended she begin physical therapy to strengthen her atrophied muscles. Upon examining her lower body muscle strength, you notice her inability to stand on one leg without collapsing to the side. Which muscle would you strengthen to increase ambulation and promote a normal walking pattern?

A) The gluteus maximus because it performs hip extension. A weakness in this area would cause her to collapse when moving from double leg to single leg stance
B) The gluteus medius because it performs hip abduction and lies on the lateral surface of the greater trochanter, preventing the hip adduction moment when standing on one leg*

C) The gluteus medius because it performs hip abduction and lies on the anterior surface of the greater trochanter, preventing the femur from dropping
D) The tensor fascia lata because it assists in hip flexion, preventing collapse.

Gluteus medius is the best answer because not only does it perform hip abduction which prevents the femur from dropping upon unilateral stance, but it also lies over the lateral aspect of the greater trochanter of the femur (whereas gluteus minimus does not).

18. A 30 year-old male trucker has come to the clinic complaining of severe pain in his right hip and the back of his leg. He describes the pain as a sharp electrical shock, and occasionally it feels like "pins and needles." It radiates from his hip down to his leg. He just recently began at his job and is taking significantly longer trips across the country. The structure most likely causing the nerve pain is:

A) Arthritis between L4 and L5 vertebrae compressing the nerve roots contributing to the sciatic nerve
B) Inflammation of the superior gemellus putting pressure on the sciatic nerve
C) Inflammation of the piriformis putting pressure on the sciatic nerve*
D) Inflammation of the inferior gemellus putting pressure on the sciatic nerve

The best answer is C. The sciatic nerve runs underneath the piriformis and when it is inflamed it is a common cause of sciatic nerve pain. The gemmeli run inferiorly to the sciatic nerve and would be less likely to irritate it. The trucker is very young and just began his job so arthritis would be less likely the culprit than the piriformis being irritated from prolonged sitting.

19. A 10-year old boy fell approximately 10 feet out of a tree on his buttocks. He is complaining of being unable to sit down on his left side and there is very little pain when palpating the sacrum. The boy is able to extend the hip with the knee extended, however there is significant pain when performing hip extension with a flexed knee. What muscle do you most suspect is injured?

A) The gluteus maximus because it is a superficial muscle and the patient is able to extend the hip with an extended knee, but not with a flexed knee.*
B) The hamstrings because the patient is able to extend the hip with an extended, but not a flexed knee. Its origin is also on the ischial tuberosity.
C) The gluteus minimus because it performs hip extension and is located where the pain is palpable
D) The gluteus medius because it performs hip extension and is located where the pain is palpable

The best answer is A because the gluteus maximus has assistance from the hamstrings during hip extension with the knee extended. It has a greater weakness and pain when performing extension with the knee flexed, and is the most superficial muscle in the region where the patient is experiencing pain.

20. A 23-year old marathon runner is complaining of pain on the lateral aspect of his left leg after he runs. He describes it as a dull ache and the more he runs the greater the pain becomes. The majority of his pain

is over the greater trochanter and there is some slight weakness in hip flexion on his left side. Which muscle is likely involved?

A) The piriformis because it distally attaches to the superior border of the greater trochanter
B) The obturator externus/internus because they distally attach on the medial surface of the greater trochanter
C) Gluteus minimus because it distally attaches to the anterior surface of the greater trochanter
D) The tensor fascia lata and IT band because it runs over the greater trochanter*

D is the answer because it is a common injury (as noted in the video) in runners, and it is the only muscle listed that assists in hip flexion where the patient has weakness.

Anterior Medial Thigh Topic 2

1. The medial border of the femoral triangle is made up by which structure?

   A) Inguinal ligament
   B) Sartorius
   C) Adductor longus*
   D) Adductor brevis

2. The lateral border of the femoral triangle is made up by which structure?

   A) Sartorius*
   B) Adductor longus
   C) Inguinal ligament
   D) Vastus intermedius

3. Which of these are NOT within the femoral triangle?
   A) Femoral nerve
   B) Femoral artery
   C) Inguinal lymph nodes
   D) Profunda femoris artery*

4. What is the longest muscle in the body?

   A) Adductor magnus
   B) Sartorius*
   C) Adductor longus
   D) Quadriceps

5. From medial to lateral, what is the correct order for contents in the femoral triangle?
   A) Lymphatics, empty space, vein, artery, nerve*
   B) Empty space, lymphatics, vein artery nerve
   C) Nerve, artery, vein, empty space, lymphatics
   D) Vein, artery, nerve, empty space, lymphatics

6. Which of these muscles do NOT flex the hip?

   A) Rectus femoris
   B) Iliopsoas
   C) Sartorius
   D) Vastus intermedius*

7. Which muscle's proximal attachment is on the AIIS?

   A) Rectus femoris*
   B) Sartorius
   C) Vastus intermedius
   D) Vastus lateralis

8. Which of these muscles DO NOT attach on the superior anteromedial tibia (pes anserine)?

   A) Sartorius
   B) Semimembranosus
   C) Gracilis
   D) Semitendinosus*

9. Which of these muscles crosses two joints?

   A) Rectus femoris
   B) Gracilis
   C) Vastus lateralis
   D) Sartorius
   E) A, B, and D*

10. What structures run in the subsartorial canal?

    A) Femoral artery
    B) Femoral vein
    C) Saphenous nerve
    D) All of the above*

11. Which muscles' proximal attachments are on the inferior pubic ramus?

    A) Adductor magnus
    B) Adductor brevis
    C) Adductor longus
    D) Gracilis
    E) Both A and B*

12. Which muscle(s) proximal attachments are on the superior pubic ramus?

    A) Pectineus*
    B) Adductor magnus
    C) Adductor brevis
    D) Gracilis
    E) Both A and B

13. Which muscle in the adductor compartment crosses the knee joint?

    A) Gracilis*
    B) Adductor longus
    C) Adductor brevis
    D) Adductor magnus

14. Which adductor(s) do not attach to the linea aspera?
    A) Gracilis

B) Pectineus
C) Adductor longus
D) Both A and B*
E) Both A and C

15. Which nerve tends to lie just deep to adductor longus?

A) Obturator nerve*
B) Femoral nerve
C) Saphenous nerve
D) External pudendal nerve

7. A 30-year old male comes to the clinic complaining of severe pain on the medial aspect of the knee (pes anserine) after horseback riding. He is also very sore on his inner-thigh area and is weak in performing hip adduction. Which muscle do you suspect is strained?

A) Sartorius because it inserts on the pes anserine and performs abduction
B) Gracilis because it inserts on the pes anserine and performs adduction*
C) Semitendinosus because it inserts on the pes anserine and performs knee flexion
D) Adductor Magnus because it is the primary adductor, and is primarily where his muscle soreness is.

B is the answer because gracilis is the only adductor that inserts on the pes anserine where all of his pain is located

8. A 75-year old female just began an aquatic exercise routine at her local gym. She is having difficulty lifting her right leg up from the ground. Upon examination you notice weak hip flexion and knee extension. Which muscle do you suspect is injured?

A) Vastus intermedius because it performs knee extension where the patient is weak
B) Sartorius because it is the main hip flexor and knee extensor
C) Rectus femoris because it performs both knee extension and hip flexion.*
D) Iliopsoas because it is the main hip flexor

C is the answer because it is the only muscle involved that is a major hip flexor and knee extensor. Sartorius and iliopsoas do not extend the knee, and vastus intermedius does not flex the hip.

18. A 45-year old runner is complaining of antero-medial knee pain and upon examination you notice patellar tracking issues. Manual muscle tests reveal a muscle weakness in knee extension on her affected knee. The muscle you suspect weak is:

A) The vastus lateralis quadriceps muscle because it would pull the patella outward causing the patella to track laterally (location of the pain)*
B) The vasus medialis quadriceps muscle because it performs knee extension and pulls the patella medially

C) The tensor fascia latae because a weakness in this muscle would cause patellar tracking issues and is on the lateral aspect of the leg
D) Biceps femoris because it is on the lateral aspect of the thigh

A is the answer because a weakness in the laterall pull of the patella would cause it to track medially, causing pain.

19. A 25 year-old ballet dancer is complaining of pain with hip flexion in performing her pirouettes. Upon muscle strength testing you notice difficulty and pain in hip flexion in a seated position. There is slight pain but not as great when sitting up from a supine position. What muscle do you expect to be involved?

A) Rectus femoris because it performs hip flexion and would not primarily be involved in sitting from a supine position*
B) Rectus abdominus because there is pain with sitting up
C) Iliopsoas because it performs hip and trunk flexion
D) Adductor longus and brevis because they help perform hip flexion and are often injured in ballet dancers

A is the answer because there is not significant weakness when sitting from supine (iliopsoas).

20. A MMA fighter got kicked during a fight in his left anterior hip. He has significant bruising in the area. Upon examination you notice he has difficulty performing hip flexion and some pain with knee extension. There is pain just below the ASIS. Which muscle do you suspect is bruised?

A) The Sartorius because it originates on the ASIS and its muscle belly is just inferior
B) The iliopsoas because it performs hip flexion and crosses the hip where the bruising is present
C) The rectus femoris because it originates on the AIIS and performs hip flexion and knee extension*
D) Quadriceps muscle because it has a large muscle belly in the area of bruising and pain

C is the answer because it is the only muscle that performs knee extension and hip flexion and originates on the AIIS.

Compartments/innervations/BS Topic 3

1. How are the four compartments for the thigh separated?

   A) Gluteal, anterior thigh, posterior thigh, medial thigh*
   B) Anterior thigh, posterior thigh, medial thigh, lateral thigh
   C) Gluteal, anterior hip, posterior thigh, medial thigh
   D) None of these

2. The sacral plexus contains which nerve roots?

   A) S2, S3, S4, S5
   B) S1, S2, S3, S4*
   C) L5, S1, S2, S3, S4
   D) S1, S2, S3, S4, S5

3. If a patient presented with numbness on the patella and medial aspect of their lower leg, which dermatome would you suspect?

   A) L3
   B) L4*
   C) L5
   D) S1

4. A football player was just tackled and presented to you with lower back pain, numbness and tingling on the anterior thigh, and had difficulty performing knee extension, which nerve roots would you suspect are involved?

   A) L1-L3
   B) L2-L5
   C) L2-L4*
   D) L5-S1

5. Select the answer that best matches each segment with its primary innervation(s).

   A) Gluteal → Superior/Inferior gluteal
   B) Medial → Femoral and Sciatic
   C) Posterior → Obturator
   D) Anterior → Femoral
   E) Both A and D*
   F) None

6. The sacral plexus supplies which segments?

   A) Everything below the knee joint
   B) Gluteal and posterior thigh
   C) Gluteal and anterior thigh
   D) Anterior and Medial thigh

E) Both A and B*

7. The lumbar plexus supplies which segments?

A) Posterior and medial thigh
B) Anterior and medial thigh*
C) Gluteal and posterior thigh
D) Anterior and posterior thigh

8. The inferior gluteal nerve innervates which muscle(s)?
A) gluteus maximus*
B) gluteus medius
C) gluteus minimus
D) TFL

9. The tibial division of the sciatic nerve innervates which muscle(s)?
A) biceps femoris (long head)
B) semimembranosus
C) semitendinosus
D) both a and b
E) a,b, and c are correct *

10. Which nerve courses through the greater sciatic foramen, runs superior to the piriformis muscle and innervates TFL?
A) pudendal nerve
B) sciatic nerve
C) inferior gluteal nerve
D) superior gluteal nerve*

11. Which nerve roots contribute to the formation of the lumbar plexus?
A) L1-L5
B) T12-L4*
C) T12-L5
D) L1-S1

12. Which nerve roots form the lumbo-sacral trunk (the nervous tissue which connects the lumbar plexus with the sacral plexus)?
A) L3-L4
B) L4-L5*
C) L5-S1
D) L5-S2

13. Which nerve roots contribute to the formation of the sciatic nerve?
A) L4-S3*
B) L4-S4
C) L4-S2
D) L4-S1

14. A patient presents with an L4-L5 herniated disk that has manifested with motor deficits/symptoms; which of the following muscles has absolutely no chance of being affected by this medical condition?

A) gluteus maximus
B) TFL
C) biceps femoris (long head)
D) biceps femoris (short head)
E) all muscles could possibly be affected*

15. The muscles of the posterior compartment of the thigh mainly receive blood from which artery (pick the most correct answer)?

A) superior gluteal artery
B) inferior gluteal artery
C) Femoral artery
D) profunda femoris artery*
E) popliteal artery

16. A 30-year old semi-professional football player fell and hyperextended his lower back. He is reporting some loss of sensation in his legs. Upon manual muscle testing, he shows weakness in hip extension and abduction. MRI reveals a possible disc herniation in L4/L5. Which muscles do you suspect are affected?

A) Piriformis because it is a part of the sacral plexus (L4-S4)
B) Gluteus maximus because it performs hip extension and is innervated by inferior gluteal nerve
C) Tensor fascia lata because it performs hip abduction and is innervated by the superior gluteal nerve
D) Quadratus femoris because it is innervated by the nerve to quadratus femoris
E) Both B and C*

The answer is E. Even though quadratus femoris gets innervations from L5, the weakness is in hip extension and abduction (which the quadratus femoris does not perform). Piriformis would not be affected by L4/L5.

17. A 24 year-old male was squatting heavy weight when he felt a sharp pain in his low back. He later began to notice lack of sensation on the lateral aspect of the 5th toe and mu^{sc}le weakness in knee flexion. MRI revealed a disc herniation. Which disc is most likely affected?

A) L2-L3 because of the lack of sensation over lateral aspect of 5th toe
B) L3-L4 ^{be}cause of pain present in his lower back
C) L4-L5 because this is the most common site for disc herniation and there is weakness in knee flexion
D) L5-S1 because there is weakness in knee flexion and decreased sensation*

18. After a motor vehicle accident, a 53 year-old male presents with muscle weakness, lack of sensation to touch, and his lumbar plexus is found to be disrupted. Muscles in which compartment(s) would be affected?

A) Gluteal compartment because muscles in this compartment receive innervation from superior and inferior gluteal nerves
B) Posterior compartment because muscles in this compartment receive innervation mainly from the sciatic nerve
C) Anterior compartment because muscles in this compartment receive innervations from the femoral nerve
D) Medial compartment because muscles in this compartment receive innervations from the obturator nerve
E) Both C and D *

19. A 92-year-old woman presents with extreme hip pain and reports no incidence of falling or injury to the area. An X-ray reveals a fracture on the femoral neck that appears to have developed through ischemic conditions. Which blood vessel(s) are most likely affected?

A) Medial circumflex femoral artery because it anastomoses with the lateral circumflex femoral artery and wraps around the neck of the femur*
B) Inferior gluteal artery because it branches towards the femur from the internal iliac artery and supplies the muscles that stabilize the femoral head in the acetabulum
C) Obturator artery because after if pierces the obturator foramen it then mainly supplies the neck of the femur
D) Profunda femoris because it runs parallel with the length of the femur sending branches to supply the bone

20. A 45-year old brick mason has had chronic back pain for years and is now starting to present with numbness and tingling on the anterolateral portion of the leg. Upon manual muscle testing you note weakness in gluteus minimus, gluteus medius, tensor fascia lata, and gluteus maximus. Which nerve root is affected?

A) L3 because its dermatome lies on the anterior thigh where the patient presents with numbness and tingling
B) L4 because its dermatome lies on the anterior thigh and there is weakness in the tensor fascia lata
C) L5 because its dermatome is on the anterior thigh and there is weakness in the muscles listed above*
D) S1 because there is significant weakness in the gluteals

The answer is C because the only dermatome/nerve root that all of these muscles have in common is L5. The dermatome is on the anterolateral aspect of the thigh.

Appendix D

NASA TLX Workload Survey

Learners will choose a number between 0 and 100 and type the number into the electronic survey as their response.

Effort:

a. How hard did you have to work in your attempt to understand the contents of the learning environment?

0 (Very low)	100 (Very high)

Mental Demand:

a. How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc.)?

0 (Very low)	100 (Very high)

b. Was the learning task easy or demanding?

0 (Very low)	100 (Very high)

Performance:

a. How successful do you think you were in understanding the contents?

0 (Good)	100 (Very poor)

b. How satisfied were you with your performance in accomplishing the learning task?

0 (Good)	100 (Very poor)

Frustration Level:

a. How frustrated were you during the learning task?

0 (Very low)	100 (Very high)

Appendix E
Elaboration Rubric

	Exceeds Expectation 3	Meets Expectation 2	Does Not Meet Expectation 1
Step 1 Case Presentation	Analyzed the presentation, signs and symptoms in the case for possible outcomes	Identified the presentation, signs and symptoms	Did not identify presentation, signs or symptoms
Step 2 Origin, insertion, action	Analyzed the action, origin and insertion of muscles or innervation/blood supply for possible outcomes	Identified action, origin, and insertion of muscles or innervation/blood supply	Did not identify action, origin or insertion of muscles
Step 3 Imaging or Tests	Analyzed tests or imaging with justification of choice including cost/efficiency/time	Identified tests or imaging with explanation of expected result	Identified test with no explanation of what is expected
Step 4 Differentials	Analyzed top 3 differentials with justification of choice and sources cited	Identified top 3 differentials with explanation of why chosen	Identified less than 3 differentials or no explanation of why chosen

Appendix F
Training for Instructor-Created Elaborations

Group Instructor-createdInstructor-created
How to study and self-reflect on Anatomy examples

Studying examples is a skill that requires some practice. In this study, you will study examples, created by your instructors, three different times. Print these directions out so you have them in front of you every time you study the instructor examples because you will answer some self-reflection questions and submit your answers in Blackboard. Self-reflection questions help you to think about *why* the instructor example is a good one. Each of the three times you turn in answers, you will receive feedback to help you improve your performance for the next time.

After watching the supplemental video, you will be given an example to study.

To help you do the best job possible, here is a good example:

<u>Step 1:</u> Your instructor provided this text in bold font as an example to help you learn the anatomy of a region:

A 22 year-old female soccer player presents to the emergency department with a swollen right ankle after twisting it at a soccer game. The player reports falling on the ankle and hearing an audible "pop" after going up for a "header" with several other players. The ankle is swollen, bruised and tender to palpation. The player reported playing on the ankle for a few more minutes before leaving the game. The athletic trainer sent her to the emergency department after the game.

You will have to answer this question: Why is this a good case to help you learn the region? How will it help you to better identify the action, origin and insertion of muscles and/or the innervation and or the blood supply in that region?

Here is a good example of a Self-Reflection Answer: *This is a good case to learn the anatomy of the ankle because it is a common injury and could involve many structures that can be included in the differential diagnosis. Because this case could involve multiple muscles, identifying the origin, insertion, and actions of these muscles will help determine which one is injured. Muscles involved would depend on the mechanism of injury. If the patient inverted her ankle, then the muscles on the lateral aspect of her leg would be affected: peroneus longus and brevis, and peroneus tertius. Ligaments could also be involved (anterior talofibular ligament).*

<u>Step 2</u>: What are the origin, insertion and action of the muscle(s) involved?

Fibularis Brevis:

Origin: Lower 1/3 of lateral surface of the fibula
Insertion: Lateral side of ht ebase of the 5th metatarsal
Action: Everts and plantarflexes the foot and supports the lateral longitudinal arch of the foot

Fibularis Longus

Origin: Lateral condyle of the tibial head and upper 2/3 of lateral surface of fibula
Insertion: Base of the 1st metatarsal and adjacent medial cuneiform
Action: Everts and plantarflexes the foot and supports the lateral longitudinal and transverse arches of the foot

Fibularis Tertius:

Origin: Inferior and anterolateral surface of the fibula
Insertion: dorsal surface and base of the 5th metatarsal bone
Action: Everts and dorsiflexes the foot

You will have to answer this question: Why is this a good example of a case study to learn the origin, insertion, and action of the muscles involved?

Here is a good example of a Self-Reflection Answer: *With an ankle sprain, depending on the severity, it could involve many muscles and structures. It is important to refresh on these origins, insertions, and actions in order to include them in or rule them out of your differential diagnosis. This will help you learn them with a contextual purpose as opposed to just memorizing them now and forgetting them later.*

<u>Step 3</u>: What imaging or tests would be helpful?

Answer: Special tests such as the anterior drawer test (to test anterior talofibular ligament) and manual muscle tests to determine which muscles are compromised. An xray is probably necessary to rule out any fractures. Depending on the severity of the sprain an MRI might be necessary to determine if there is a significant tear. Ultrasound is also a potential alternative to an MRI as it can detect a muscle tear.

Include the answers to these self-reflection questions in your responses: Why would these be helpful tests? What would you expect to find in the results?

Here is a good example of a self-reflection answer: *An xray would rule out an avulsion fracture since the patient heard a "pop". I would expect to find an xray negative for a fracture, however, an MRI might reveal a high ankle sprain in which the interosseus membrane is damaged between the tibia and fibula. Also, it would reveal a torn anterior talofibular ligament (ATF) and manual muscle tests would reveal a grade 2 or 3 sprain of the fibularis muscles.*

<u>Step 4</u>: What are the three most plausible differentials?

The most plausible differentials are an ATF ligament tear, a grade 2 or 3 muscle sprain of the fibularis muscles, and possibly a high ankle sprain involving the interosseus membrane.

Here is a good example of a Self-Reflection Answer:
Explain how you know these are the three most plausible differentials.

When an ankle is inverted, the ATF is usually the primary ligament involved in a sprain. The fibularis muscles are also usually involved in ankle inversion because they are the ankle everters and would get stretched/strained upon forceful inversion. Also, upon palpation, inspection, and manual muscle testing it would be clear which muscles would be involved. Xray and MRI would confirm the diagnosis and determine the severity of the ankle sprain.

OK, now you have seen a great example, let's look at a not so great one. Notice the lack of detail in the answer. Essentially the information is correct, but there is not enough detail to show your complete understanding.

<u>Step 1</u>: Your instructor provided this example to help you learn the anatomy of a region:

A 22 year-old female soccer player presents to the emergency department with a swollen right ankle after twisting it at a soccer game. The player reports falling on the ankle and hearing an audible "pop" after going up for a "header" with several other players. The ankle is swollen, bruised and tender to palpation. The player reported playing on the ankle for a few more minutes before leaving the game. The athletic trainer sent her to the emergency department after the game.

You will have to answer this question: Why is this a good case to help you learn the region? How will it help you to better identify the action, origin and insertion of muscles and/or the innervation and or the blood supply in that region?

Here is a poor example of a Self-Reflection Answer: *This is a good case to learn the anatomy of the ankle because it is a common injury.*

<u>Step 2</u>: Your instructor provides this part: What are the origin, insertion and action of the muscle(s) involved?

Fibularis Brevis:

Origin: Lower 1/3 of lateral surface of the fibula
Insertion: Lateral side of the base of the 5th metatarsal

Action: Everts and plantarflexes the foot and supports the lateral longitudinal arch of the foot

Fibularis Longus

Origin: Lateral condyle of the tibial head and upper 2/3 of lateral surface of fibula

Insertion: Base of the 1st metatarsal and adjacent medial cuneiform

Action: Everts and plantarflexes the foot and supports the lateral longitudinal and transverse arches of the foot

Fibularis Tertius:

Origin: Inferior and anterolateral surface of the fibula

Insertion: dorsal surface and base of the 5th metatarsal bone

Action: Everts and dorsiflexes the foot

You will have to answer this part: Include the answers to these self-reflection questions in your responses: Why is this a good example of a case study to learn the action, insertion and origin of the muscles involved for the example?

A poor answer would be: *This is an example of a case study because it involves many muscles of the lower leg.*

Your instructor provides this example:
<u>**Step 3**</u>**: What imaging or tests would be helpful?**

Answer: Special tests such as the anterior drawer test (to test anterior talofibular ligament) and manual muscle tests to determine which muscles are compromised. An xray is probably necessary to rule out any fractures. Depending on the severity of the sprain an MRI might be necessary to determine if there is a significant tear. Ultrasound is also a potential alternative to an MRI as it can detect a muscle tear.

You will have to answer this part: Why would these be helpful tests? What would you expect to find in the results?

This is a poor answer to the self-reflection questions:
X-ray: looking for a broken bone
MRI: soft tissue damage
Manual Muscle Tests: strained muscles

Your instructor provided this example
<u>**Step 4**</u>**: What are the three most plausible differentials?**

The most plausible differentials are an ATF ligament tear, a grade 2 or 3 muscle sprain of the fibularis muscles, and possibly a high ankle sprain involving the interosseus membrane.

You will have to answer this part: Explain how you know these are the three most plausible differentials.

Here is a poor answer to these self-reflection questions: *These are the most common structures involved in an ankle sprain and therefore make the most sense as differentials.*

Appendix G
Learner-Created Elaboration Training

Directions for Group Learner-createdLearner-created

How to create your own Anatomy examples

Creating examples is a skill that requires some practice. During this study, you will create examples three different times. Print these directions out so you have them in front of you every time you create your examples to submit in Blackboard. Each step has an answer and a self-reflection component. The self-reflection component will show the thought process behind your answers. Each of the three times you turn in an example, you will receive feedback on your examples to help you improve your performance for the next time.

After watching a supplemental video, you will be given an outline to help you create your examples. Creating your examples contains four steps:

Step 1: Create a case about a region and include presentation, signs and symptoms.

Self-reflection prompt: As you go through the creation process of this step, include the answers to these self-reflection questions in your responses: Why is this a good case to help you learn the region? How will it help you to better identify the action, origin and insertion of muscles and/or the innervation and or the blood supply in that region?

Step 2: What are the origin, insertion and action of the muscle(s) involved?

Self-reflection prompt: Include the answers to these self-reflection questions in your responses: Why is this a good example of the action, insertion and origin of the muscles involved for the example?

Step 3: What imaging or tests would be helpful?

Self-reflection prompt: Include the answers to these self-reflection questions in your responses: Why would these be helpful tests? What would you expect to find in the results?

Step 4: What are the three most plausible differentials?

Self-reflection prompt: Include the answers to these self-reflection questions in your responses: Explain how you know these are the three most plausible differentials.

Take a look at a good example on the next page.

To help you do the best job possible, this is what a good example would look like:

Step 1: Create a case about a region and include presentation, signs and symptoms.

Your Step 1 answer could be: A 22 year-old female soccer player presents to the emergency department with a swollen right ankle after twisting it at a soccer game. The player reports falling on the ankle and hearing an audible “pop” after going up for a “header” with several other players. The ankle is swollen, bruised and tender to palpation. The player reported playing on the ankle for a few more minutes before leaving the game. The athletic trainer sent her to the emergency department after the game.

Self-reflection prompt: Why is this a good case to help you learn the region? How will it help you to better identify the action, origin and insertion of muscles and/or the innervation and or the blood supply in that region?

Your Self Reflection Answer could be: This is a good case to learn the anatomy of the ankle because it is a common injury and could involve many structures that can be included in the differential diagnosis. Because this case could involve multiple muscles, identifying the origin, insertion, and actions of these muscles will help determine which one is injured. Muscles involved would depend on the mechanism of injury. If the patient inverted her ankle, then the muscles on the lateral aspect of her leg would be affected: peroneus longus and brevis, and peroneus tertius. Ligaments could also be involved (anterior talofibular ligament).

Step 2: What are the origin, insertion and action of the muscle(s) involved?

Your Step 2 Answer could be:
Fibularis Brevis:

Origin: Lower 1/3 of lateral surface of the fibula
Insertion: Lateral side of ht ebase of the 5th metatarsal
Action: Everts and plantarflexes the foot and supports the lateral longitudinal arch of the foot

Fibularis Longus

Origin: Lateral condyle of the tibial head and upper 2/3 of lateral surface of fibula
Insertion: Base of the 1st metatarsal and adjacent medial cuneiform
Action: Everts and plantarflexes the foot and supports the lateral longitudinal and transverse arches of the foot

Fibularis Tertius:

Origin: Inferior and anterolateral surface of the fibula
Insertion: dorsal surface and base of the 5th metatarsal bone
Action: Everts and dorsiflexes the foot

Self-reflection prompt: Include the answers to these self-reflection questions in your responses: Why is this a good example of a case study to learn the origin, insertion, and action of the muscles involved?

Your Step 2 Self Reflection answer could be: With an ankle sprain, depending on the severity, it could involve many muscles and structures. It is important to refresh on these origins, insertions, and actions in order to include them in or rule them out of your differential diagnosis. This will help you learn them with a contextual purpose as opposed to just memorizing them now and forgetting them later.

Step 3: What imaging or tests would be helpful?

Your Step 3 Answer could be: Special tests such as the anterior drawer test (to test anterior talofibular ligament) and manual muscle tests to determine which muscles are compromised. An xray is probably necessary to rule out any fractures. Depending on the severity of the sprain an MRI might be necessary to determine if there is a significant tear. Ultrasound is also a potential alternative to an MRI as it can detect a muscle tear.

Self-reflection prompt: Include the answers to these self-reflection questions in your responses: Why would these be helpful tests? What would you expect to find in the results?

Your Step 3 Self Reflection answer could be: An xray would rule out an avulsion fracture since the patient heard a “pop”. I would expect to find an xray negative for a fracture, however, an MRI might reveal a high ankle sprain in which the interosseus membrane is damaged between the tibia and fibula. Also, it would reveal a torn anterior talofibular ligament (ATF) and manual muscle tests would reveal a grade 2 or 3 sprain of the fibularis muscles.

Self-reflection prompt: Step 4: What are the three most plausible differentials?

Your Step 4 Answer could be: The most plausible differentials are an ATF ligament tear, a grade 2 or 3 muscle sprain of the fibularis muscles, and possibly a high ankle sprain involving the interosseus membrane.

Include the answers to these self-reflection questions in your responses: Explain how you know these are the three most plausible differentials.

Your Step 4 Self Reflection could be: When an ankle is inverted, the ATF is usually the primary ligament involved in a sprain. The fibularis muscles are also usually involved in ankle inversion because they are the ankle everters and would get stretched/strained upon forceful inversion. Also, upon palpation, inspection, and manual muscle testing it would be clear which muscles would be involved. Xray and MRI would confirm the diagnosis and determine the severity of the ankle sprain.

OK, now you have seen a great example, let's look at a not so great one. Notice the lack of detail in the answer. Essentially the information is correct, but there is not enough detail to show your complete understanding.

Step 1: Create a case about a region and include presentation, signs and symptoms.

Your poor Step 1 answer could be: *A 22 year-old female soccer player presents to the emergency department with a swollen right ankle after twisting it at a soccer game.*

Self-reflection prompt: Why is this a good case to help you learn the region? How will it help you to better identify the action, origin and insertion of muscles and/or the innervation and or the blood supply in that region?

Your poor self-reflection answer could be:
Because it is a common injury

Step 2: What are the origin, insertion and action of the muscle(s) involved?

Your Step 2 Answer will be: (this part everyone should be able to get, it's either right or wrong)
Fibularis Brevis:

Origin: Lower 1/3 of lateral surface of the fibula
Insertion: Lateral side of the base of the 5th metatarsal
Action: Everts and plantarflexes the foot and supports the lateral longitudinal arch of the foot

Fibularis Longus

Origin: Lateral condyle of the tibial head and upper 2/3 of lateral surface of fibula
Insertion: Base of the 1st metatarsal and adjacent medial cuneiform
Action: Everts and plantarflexes the foot and supports the lateral longitudinal and transverse arches of the foot

Fibularis Tertius:

Origin: Inferior and anterolateral surface of the fibula
Insertion: dorsal surface and base of the 5th metatarsal bone
Action: Everts and dorsiflexes the foot

Self Reflection Prompt: Include the answers to these self-reflection questions in your responses: Why is this a good example of a case study to learn the action, insertion and origin of the muscles involved for the example?

Your poor self-reflection answer could be:
This is a good example of a case study because it involves many muscles of the lower leg.

Step 3: What imaging or tests would be helpful?

Your poor answer could be:
X-ray, MRI, manual muscle tests.

Self Reflection Prompt: Include the answers to these self-reflection questions in your responses: Why would these be helpful tests? What would you expect to find in the results?

Your poor self-reflection answer could be:
X-ray: looking for a broken bone
MRI: soft tissue damage
Manual Muscle Tests: strained muscles

Step 4: What are the three most plausible differentials?

Your poor answer could be:

1. *Ankle sprain*
2. *Ankle strain*
3. *Fracture*

Self-Reflection Prompt: Include the answers to these self-reflection questions in your responses: Explain how you know these are the three most plausible differentials.

Your poor self-reflection answer could be:
These are the most common structures involved in an ankle sprain and therefore make the most sense as differentials.

Appendix H
Outline for Learner-Created Elaborations

After watching a supplemental video, use this outline to help you create your examples. Creating your examples contains four steps:

Step 1: Create a case about a region and include presentation, signs and symptoms.
Place your case here

Self-reflection prompt: As you go through the creation process of this step, include the answers to these self-reflection questions in your responses: Why is this a good case to help you learn the region? How will it help you to better identify the action, origin and insertion of muscles and/or the innervation and or the blood supply in that region?
Place your answers here

Step 2: What are the origin, insertion and action of the muscle(s) involved?
Place your answers here

Self-reflection prompt: Include the answers to these self-reflection questions in your responses: Why is this a good example of the action, insertion and origin of the muscles involved for the example?
Place your answers here

Step 3: What imaging or tests would be helpful?
Place your answers here

Self-reflection prompt: Include the answers to these self-reflection questions in your responses: Why would these be helpful tests? What would you expect to find in the results?
Place your answers here

Step 4: What are the three most plausible differentials?
Place your answers here

Self-reflection prompt: Include the answers to these self-reflection questions in your responses: Explain how you know these are the three most plausible differentials.

Place your answers here

Appendix I
Completed Learner-Created Elaboration with Reflection

Step 1: Create a case about a region and include presentation, signs and symptoms.
A 22 year-old female soccer player presents to the emergency department with a swollen right ankle after twisting it at a soccer game. The player reports falling on the ankle and hearing an audible “pop” after going up for a “header” with several other players. The ankle is swollen, bruised and tender to palpation. The player reported playing on the ankle for a few more minutes before leaving the game. The athletic trainer sent her to the emergency department after the game.

Self-reflection prompt: Why is this a good case to help you learn the region? How will it help you to better identify the action, origin and insertion of muscles and/or the innervation and or the blood supply in that region?

This is a good case to learn the anatomy of the ankle because it is a common injury and could involve many structures that can be included in the differential diagnosis. Because this case could involve multiple muscles, identifying the origin, insertion, and actions of these muscles will help determine which one is injured. Muscles involved would depend on the mechanism of injury. If the patient inverted her ankle, then the muscles on the lateral aspect of her leg would be affected: peroneus longus and brevis, and peroneus tertius. Ligaments could also be involved (anterior talofibular ligament).

Step 2: What are the origin, insertion and action of the muscle(s) involved?

Fibularis Brevis:
  Origin: Lower 1/3 of lateral surface of the fibula
  Insertion: Lateral side of ht ebase of the 5th metatarsal
  Action: Everts and plantarflexes the foot and supports the lateral longitudinal arch of the foot
Fibularis Longus
  Origin: Lateral condyle of the tibial head and upper 2/3 of lateral surface of fibula
  Insertion: Base of the 1st metatarsal and adjacent medial cuneiform
  Action: Everts and plantarflexes the foot and supports the lateral longitudinal and transverse arches of the foot
Fibularis Tertius:
  Origin: Inferior and anterolateral surface of the fibula
  Insertion: dorsal surface and base of the 5th metatarsal bone
  Action: Everts and dorsiflexes the foot

Self-reflection prompt: Include the answers to these self-reflection questions in your responses: Why is this a good example of a case study to learn the origin, insertion, and action of the muscles involved?

With an ankle sprain, depending on the severity, it could involve many muscles and structures. It is important to refresh on these origins, insertions, and actions in order to include them in or rule them out of your differential diagnosis. This will help you learn them with a contextual purpose as opposed to just memorizing them now and forgetting them later.

Step 3: What imaging or tests would be helpful?

Special tests such as the anterior drawer test (to test anterior talofibular ligament) and manual muscle tests to determine which muscles are compromised. An xray is probably necessary to rule out any fractures. Depending on the severity of the sprain an MRI might be necessary to determine if there is a significant tear. Ultrasound is also a potential alternative to an MRI as it can detect a muscle tear.

Self-reflection prompt: Include the answers to these self-reflection questions in your responses: Why would these be helpful tests? What would you expect to find in the results?

An xray would rule out an avulsion fracture since the patient heard a “pop”. I would expect to find an xray negative for a fracture, however, an MRI might reveal a high ankle sprain in which the interosseus membrane is damaged between the tibia and fibula. Also, it would reveal a torn anterior talofibular ligament (ATF) and manual muscle tests would reveal a grade 2 or 3 sprain of the fibularis muscles.

Self-reflection prompt: Step 4: What are the three most plausible differentials?

The most plausible differentials are an ATF ligament tear, a grade 2 or 3 muscle sprain of the fibularis muscles, and possibly a high ankle sprain involving the interosseus membrane.

Include the answers to these self-reflection questions in your responses: Explain how you know these are the three most plausible differentials.

When an ankle is inverted, the ATF is usually the primary ligament involved in a sprain. The fibularis muscles are also usually involved in ankle inversion because they are the ankle everters and would get stretched/strained upon forceful inversion. Also, upon palpation, inspection, and manual muscle testing it would be clear which muscles would be involved. Xray and MRI would confirm the diagnosis and determine the severity of the ankle sprain.

Appendix J

Adjunct Questions After Video

Adjunct Questions
Medial Thigh

1. A recreationally active 24 year-old female complains of low-back pain since she began to increase her activity level; specifically adding rowing to her routine. Upon muscle strength testing you notice difficulty sitting up from a supine position, and hip flexion. What muscle would you expect to be involved?
    a. Rectus femoris because it performs hip flexion and tightness could pull on the pelvis causing back pain.
    b. Rectus abdominus because she is having difficulty sitting up.
    c. Iliopsoas because it originates on the low back, and performs hip and trunk flexion.*
    d. Adductor longus and brevis because they help perform hip flexion.

C is the answer

2. A 36 year old week-end warrior recently began to feel pain on the medial side of his femur immediately proximal to the knee joint. Manual muscle tests revealed that slight weakness was present in the adducting motion of the hip. What is the most likely cause of this individual's pain?
    a. An inferior adductor longus muscle strain or avulsion fracture
    b. an inferior vastus medialis muscle strain
    c. an inferior gracilis muscle strain or avulsion fracture
    d. an inferior adductor magnus muscle strain or avulsion fracture*
    e. an inferior pectineus muscle strain or avulsion fracture

9. **is the answer because its attachment to the adductor tubercle is just proximal to the medial knee joint (explains the pain) and it is a very strong adductor which would allow for the presence of weakness if it were compromised (longest moment arm of the adductors**)

Anterior Thigh

1. A high school soccer player complained of hip pain after being kicked by a player while sliding to get the ball. He explained that the hip bone (ASIS) hurts to touch and it hurts to run. Upon examination he has difficulty performing hip flexion, hip abduction, and hip external rotation. It also hurts to stretch the hip into extension. The muscle most likely involved is
    a. The iliacus because it performs hip flexion and crosses the hip where he has pain.
    b. The rectus femoris because it performs hip flexion and is attached to the ASIS where the pain is palpable
    c. The Sartorius because it performs the motions the patient has difficulty in, and it originates where there is pain*
    d. The vastus (quadriceps) muscles because they originate on the anterior hip where the

patient presents pain.

C is the answer

2. A 75 year-old female is complaining of right antero-lateral knee pain and upon examination you notice patellar tracking issues. Manual muscle tests reveal a muscle weakness in knee extension on her affected knee. The muscle you suspect is weak is:
   a. The vastus lateralus quadriceps muscle because it lies on the outside of the leg and would pull the knee outward causing the patella to track laterally.
   b. The vastus medialis quadriceps muscle because it performs knee extension and pulls the patella medially.*
   c. The gracilis because a weakness in this muscle would cause patellar tracking issues.
   d. Biceps Femoris because it is on the lateral aspect of the thigh.

B. is the answer because a weakness in the vastus medialis would cause the patella to track laterally causing anterolateral knee pain.

Posterior Thigh

10. A 60 year-old male is complaining of a muscle strain on his right leg after attempting to lift a heavy object in a straight legged-position. His pain is located just above the knee on the postero-medial aspect of the thigh. Upon examination you notice weakness and pain during knee flexion during hip internal rotation. The muscle most likely affected is:

A. The semi-tendinosis due to the fact that it flexes the knee and is located on the medial aspect of the knee.
B. The biceps femoris because it performs knee flexion and is the strongest of the flexors
C. The semi-membranosis because it flexes the knee on the medial aspect and there is vascularized muscle tissue right where there is pain*
D. The gracilis because it inserts at the same place as the medial hamstrings and may play some role in knee flexion due to its origin and insertion.

The answer is C because the muscle belly and vascularized tissue is in the area of pain, whereas with the semi-tendinosis there is just tendon. This is a muscle strain.

11. A 21-year old ODU learner was walking at 2 in the morning alone on Killam Ave after a party. He heard a series of “pops” and felt a pain in the buttocks region. Upon examination you notice a 9mm gunshot wound that is fairly deep. The muscles you know to be injured are:

A. The gluteus maximus only as it is the main muscle in the area
B. The gluteus maximus and the hamstrings because the patient is having trouble with hip extension
C. The gluteus maximus because the patient is able to extend the hip with an extended knee, but not with a flexed knee*
D. The hamstrings because the patient is able to extend the hip with an extended, but not with a flexed knee.

The answer is C because the hamstrings are activated when the knee is extended. We know the gluteus maximus to be involved as it is the most superficial muscle and there is clearly a bullet in there. The hamstrings can be ruled out because they perform the hip extension when the glutes cannot.

Appendix K
Topic Objectives

Topic 1 – Gluteal and Posterior Thigh – muscular and skeletal
Identify the major bony and ligamentous structures of the pelvis and femur.
Identify the gluteal muscles and the six lateral rotators in terms of attachments, and actions.
Identify the muscles of the hamstring group in terms of attachments, and actions.

Topic 2 – Anterior and Medial Thigh- muscular and skeletal
Identify the deep fascia of the thigh and the intermuscular septa.
Identify the femoral triangle, the adductor canal, and the contents of each.
Identify the anatomy of the hip and knee joints with reference to bony and ligamentous structures.
Identify the muscles in the anterior and medial compartments of the thigh with respect to attachments and actions.
Topic 3 – Compartment/Innervation/Blood Supply Medial Thigh – innervation, blood supply, and identification of compartments
Identify the blood supply to, and venous drainage of, the gluteal region and posterior thigh.
Identify the innvervation of the gluteal and posterior thigh and the anteromedial thigh
Identify the deep and superficial venous drainage of the thigh.
Identify the boundaries and contents of the popliteal fossa.
Identify the course, and distribution, of the sciatic, superior and inferior gluteal nerves.
Identify the course, and distribution, of the branches of the femoral artery.
Identify the muscles in the anterior and medial compartments of the thigh with respect to innervation.

Appendix L
Applied Cognitive Task Analysis

Task Diagram
Step 1: Watch 2 main lecture videos, attend 2 main dissection sessions. After attending to videos of both lectures and performing the dissection sessions, go to next step.
Step 2: Watch a supplemental video about the material in the lectures divided into three related topic areas:
Step 3: Experience a treatment (answer questions or study examples, or create an example or watch the supplemental video again).
Step 4: Take a multiple choice question (MCQ) test
Step 5: Take a workload survey.
Step 6: Repeat Steps 2-5 two more times
Topic Breakdown:
Topic 1 Gluteal and Posterior Thigh – muscular and skeletal
Identify the major bony and ligamentous structures of the pelvis and femur.
Identify the gluteal muscles and the six lateral rotators in terms of attachments, and actions.
Identify the muscles of the hamstring group in terms of attachments, and actions.

Watch Supplemental Video on the gluteal and posterior thigh as many times as needed
Treatments by Group

Group 1 – Answer adjunct questions. Can watch video again to help answer questions
Group 2 – Instructor-createdInstructor-created Elaboration – studies an instructor-createdinstructor-created elaboration and records answers to self-reflection prompts in writing, submit to learning management system (LMS).
Group 3 – Learner-createdLearner-created Elaboration – Learners read instruction on how to create elaborations. Learners create an elaboration based on an outline provided in the LMS along with providing answers to self-reflection prompts in writing submitted to the LMS.
Group 4 – Watch supplemental video again.

Take a multiple choice test on the gluteal and posterior thigh
Take a survey about workload
Topic 2 Anterior and Medial Thigh- muscular and skeletal
Identify the deep fascia of the thigh and the intermuscular septa.
Identify the femoral triangle, the adductor canal, and the contents of each.
Identify the anatomy of the hip and knee joints with reference to bony and ligamentous structures.
Identify the muscles in the anterior and medial compartments of the thigh with respect to attachments and actions.

Watch Supplemental Video on the anterior and medial thigh as many times as needed
Treatments by Group

Group 1 – Answer adjunct questions. Can watch video again to help answer questions
Group 2 – Instructor-createdInstructor-created Elaboration – studies an instructor-createdinstructor-created elaboration and records answers to self-reflection prompts in writing, submit to learning management system (LMS).

Group 3 – Learner-created Learner-created Elaboration – Learners read instruction on how to create elaborations. Learners create an elaboration based on an outline provided in the LMS along with providing answers to self-reflection prompts in writing submitted to the LMS.

Group 4 – Watch supplemental video again.

Take a multiple choice test on the anterior and medial thigh

Take a survey about workload

Topic 3 Compartment/Innervation/Blood Supply Medial Thigh – innervation, blood supply, and identification of compartments

Identify the blood supply to, and venous drainage of, the gluteal region and posterior thigh.
Identify the innvervation of the gluteal and posterior thigh and the anteromedial thigh
Identify the deep and superficial venous drainage of the thigh.
Identify the boundaries and contents of the popliteal fossa.
Identify the course, and distribution, of the sciatic, superior and inferior gluteal nerves.
Identify the course, and distribution, of the branches of the femoral artery.
Identify the muscles in the anterior and medial compartments of the thigh with respect to innervation.

Watch Supplemental Video on the Compartment/Innervation/Blood Supply Medial Thigh as many times as needed

Treatments by Group

Group 1 – Answer adjunct questions. Can watch video again to help answer questions

Group 2 – Instructor-createdInstructor-created Elaboration – studies an instructor-createdinstructor-created elaboration and records answers to self-reflection prompts in writing, submit to learning management system (LMS).

Group 3 – Learner-createdLearner-created Elaboration – Learners read instruction on how to create elaborations. Learners create an elaboration based on an outline provided in the LMS along with providing answers to self-reflection prompts in writing submitted to the LMS.

Group 4 – Watch supplemental video again.

Take a multiple choice test on the Compartment/Innervation/Blood Supply Medial Thigh.

Take a survey about workload.

Knowledge Audit with SME

Aspect	**Cues/Strategies**	**Why This is Difficult?**
Past and Future When you were first learning anatomy, what did you do to help learn the material?	First I memorized bones and part, origins and insertions and actions. I used flash cards with text, then visualized the muscle usage on a skeleton.	A lot of initial memorization and it is difficult to visualize how it all works together
Big Picture What are the major elements you have to keep track of then learning anatomy?	The origins, insertions and actions. I would look at diagrams first then pictures, then make my own drawings or mind maps of a region	A lot of initial memorization and it is difficult to visualize how it all works together
Noticing What did you not see when you were first beginning to learn that you saw later when you became more of an expert?	At first I just tried to memorize everything, and my professor kept telling me to memorize the joint and movements first, then learn origin and insertion then once you know where the fibers are and the layering, you can understand the action. I would then learn the groups of muscles that are innervated then learn the vascular structure.	I ignored my professor's advice at first then realized it was good advice when my grades were falling and I tried that methodology, it worked!
Opportunities/improvement What changes did you make in learning as you got better in learning anatomy?	First I tried learning everything, but then I followed my professor's advice to learn to identify rules and exceptions for groups	You think you are the exception because you have always been smarter than other classmates, but this is large group of exceptional people and you may have to change the way you study
Self-Monitoring How did you realize you needed to change the way you were learning anatomy?	Grades and professor feedback, watched other classmates and how they learned. Drawing works for some learners, physical manipulation works best for me.	Grades may be hard to recover from if you wait too long to get help.

Cognitive Demands Table

Difficult Cognitive Element	**Why This is Difficult?**	**Common Errors**	**Cues and Strategies**
Great deal of memorization	Sheer volume of information in one semester	Try to memorize everything without relating it to a group	Identify rules and exceptions for each group of muscles
Visualizing everything	Each cadaver is just a little different.	Confuse similar muscles	Using a standard cadaver in a video with clear labeling from the expert. Know layers by starting in 2D drawings, then layer understanding of how each layer works together and move to 3D video to solidify understanding.

VITA

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Educational Background
Bachelor of Science, Business Administration, Management, Old Dominion University, 1980
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Professional Experience
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