Virtual Patient Simulations for Medical Education:

Increasing Clinical Reasoning Skills through Deliberate Practice

by

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ABSTRACT

Virtual Patient Simulations (VPS) are web-based exercises involving simulated patients in virtual environments. This study investigates the utility of VPS for increasing medical student clinical reasoning skills, collaboration, and engagement. Many studies indicate that VPS provide medical students with essential practice in clinical decision making before they encounter real life patients. The utility of a recursive, inductive VPS for increasing clinical decision-making skills, collaboration, or engagement is unknown.

Following a design-based methodology, VPS were implemented in two phases with two different cohorts of first year medical students: spring and fall of 2013. Participants were 108 medical students and six of their clinical faculty tutors. Students collaborated in teams of three to complete a series of virtual patient cases, submitting a ballpark diagnosis at the conclusion of each session. Student participants subsequently completed an electronic, 28-item Exit Survey. Finally, students participated in a randomized controlled trial comparing traditional (tutor-led) and VPS case instruction methods. This sequence of activities rendered quantitative and qualitative data that were triangulated during data analysis to increase the validity of findings.

After practicing through four VPS cases, student triad teams selected accurate ballpark diagnosis 92% of the time. Pre-post test results revealed that PPT was significantly more effective than VPS after 20 minutes of instruction. PPT instruction resulted in significantly higher learning gains, but both modalities supported significant learning gains in clinical reasoning. Students collaborated well and held rich clinical discussions; the central phenomenon that emerged was “synthesizing evidence inductively to make clinical decisions.” Using an inductive process, student teams collaborated to analyze patient data, and in nearly all instances successfully solved the case, while remaining cognitively engaged.

This is the first design-based study regarding virtual patient simulation, reporting iterative phases of implementation and design improvement, culminating in local theories (petite generalizations) about VPS design. A thick, rich description of environment, process, and findings may benefit other researchers and institutions in designing and implementing effective VPS.

DEDICATION

I dedicate this research to the next generation of healthcare professionals and education doctoral students. Many successes lie ahead for you, particularly if you retain your compassion and apply the skills you learn through your experiences to solve the important problems of humanity.

ACKNOWLEDGMENTS

This dissertation summarizes the development of an education innovation. I was extremely fortunate to receive expert guidance from a highly experienced dissertation committee dedicated to this process—Keith Wetzel PhD (Chair), Ann Ewbank PhD (Co-Chair), and Harvey Simon MD (Medical Faculty Member). While standards were high, these faculty were generous in providing mentorship along the way, patiently read drafts of the dissertation and challenging me to be thorough. I benefitted greatly from the community of my leader-scholar community (LSC), a small group comprised of five doctoral students and the dissertation chairs. Every few weeks we met to share experiences, discuss research methods, and review each other’s work.

Many others contributed support and deserve thanks. Fredric Schwartz DO provided medical education mentorship throughout the project. Education game expert Sasha Barab PhD advised regarding design based research principles and virtual worlds. Statistician Curt Bay PhD offered SPSS expertise. Professor Debby Zambo PhD consulted on education theory. Special thanks to the SOMA Technology-enhanced Active Learning Team for Medical Education, particularly the faculty who authored the virtual simulations Thomas Bennett DO and Noel Carrasco MD. The medical students and small group facilitators who participated exceeded expectations. I am grateful to professors Lawrence LeBeau DO, Aaron Allgood DO, Milton Pong PhD, Robert Coppola DO, Gene Winfield DO, and Charlyn Kellar, Curriculum Coordinator for hosting these learning activities. Your vision and courage to try new methods is exemplary. Michele Farr and Nick Cross volunteered time setting up and proctoring the exam. Last but not least, I would like to thank my children, Sharmishtha and Vishesh. It was a very long process, and you were amazingly patient and proactive toward your own academic achievements.

Using research to explore inductively, one does not know where things will lead, but the journey has been deeply rewarding on many levels. It was never easy, but always cognitively engaging to develop a new education innovation and evaluate its merits. Surprisingly, enthusiasm, community and synergy evolved. It has been a privilege to explore theory and practice within this creative, generative project.

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Introduction

This project explores an interactive method for engaging first-year medical students in simulated clinical decision-making. Virtual Patient Simulations (VPS) are web-based exercises involving simulated patients in virtual environments. Providing students with VPS to rehearse patient case scenarios early in their training before they encounter live patients is a safe approach to medical education (Ziv, Wolpe, Small, & Glick, 2006). Experts in medical education suggest that increasing the number of early experiential learning episodes improves the curriculum (Cooke, Irby & Obrien, 2010). VPS deliver instruction in a modality suitable for first year medical students native to an era of multi-media and web-based games (Dahlstrom, DeBoor, Grunwald, & Vockley, 2011; Gee, 2008; Johnson, 2006; Kron, Gjerde, Sen & Fetters, 2010). Educational game theorists suggest that virtual scenarios provide learning spaces in which pleasure and satisfaction are derived from increased competence (Deterding & Dixon, 2011; Gee, 2008). This paper will argue that not only do VPS increase clinical decision-making skills, but they provide collaborative, participatory learning experiences. Medical education literature suggests that training novice medical students to problem-solve like expert physicians involves teaching them to gather evidence and build schemata by early exposure to clinical experiences (Coderre, Mandin, Harasym & Fick, 2003; Eva, 2005). Literature from the business, law, science, and technology fields indicates that a modern approach to problem-solving involves forward reasoning (Carson, 2009; Patel & Groen, 1986), technology-enhanced education (Kereluik, Mishra, Fanhoe & Terry, 2013), and opportunities to experiment (Duckworth, 2006). Using these strategies, professionals learn to think deeply about issues, solve problems, and innovate (Christiansen, Horn & Johnson, 2008; Senge, 1990).

For all of these reasons, it seemed likely that a VPS designed to target inductive reasoning skills would support first-year medical students in constructing concept maps (schemata) and improve clinical reasoning processes. In 2012, medical educators constructed VPS with inductive reasoning exercises and piloted them with first-year students throughout one semester. Through an iterative process of refinement, designers and authors tested and improved the design. The learning consequences of these decision simulations bore further investigation with a more targeted study. In 2013, VPS were used for supplemental learning exercises with first-year medical school students in two subsequent implementations. Results from these episodes were analyzed to understand ways that students construct meaning from this modality of instruction. The results will add to the medical education literature on inductive clinical reasoning and virtual patient simulations, two fields of interest to educators in health professions' education.

Background and Context

National Context

The field of medical sciences is rapidly changing as a result of exploding information and technological advances (Mabry, 2011). According to experts in the field of medical information technology, in the near future, physicians will be aided by artificial intelligence and rely more heavily on cognitive extension devices such as smart phones and other electronic devices for rapid information queries (Farrell, 2011; Ferrucci, 2010). This implies that the focus of higher education should shift away from rote memorization of content toward critical thinking and creative thought processes supported by the intelligent use of technology (Mishra, 2012). As the field of medicine grows more complex, medical schools must find new ways to more efficiently train students to make effective, accurate clinical decisions. For physicians, the measure of competence is the ability to diagnose and manage patients (Ericsson, 2004; Norman, 2005). Simulations provide a low-risk context for practicing clinical encounters prior to interactions with human patients (Nishisaki, Keren, & Nadkarni, 2007; Ziv et al., 2006). In the *Checklist Manifesto*, Gawande (2009) makes a strong argument for preparing physicians better for the sake of patient safety, emphasizing that the quantity of knowledge that modern physicians daily process and organize is extensive. Reformers urge medical education curricula to reflect a collaborative, inter-professional approach to patient care (Frenk et al., 2010).

Modern educators concur that active, learner-centered instructional approaches are more successful than lecture (Cullen, Harris & Hill, 2012; Prince, 2004; Tagg, 2003; Wieman, 2004). Others emphasize that students require a 21st century skill set including critical thinking, systems-based thinking, and communication (Gee & Jenkins, 2011; Kereluik et al., 2013; Senge, 1990). For example, 21st century scientists will require the ability to quickly assess high volumes of bio-medical and contextual data through the filter of well-established problem solving schemata (Bird, 2010; Wieman, 2004). This VPS medium of instruction will benefit medical students because it will provide them with learning spaces that allow them freedom to experiment, process evidence, and collaborate in authentic scenarios (Gee & Jenkins, 2011).

Internet generation students and educational technology. The current generation of students grew up playing independent and group video games; they are accustomed to self-directed learning (Kron et al., 2010; Oblinger & Oblinger, 2005). As it developed, this project was nourished by the growing body of theory emanating from video educational game experts and their observations about video-game generation students (Barab, Scott, Siyahhan, Goldstone, Ingram-Goble, Zuiker, & Warren, 2009; Gee, 2005).

Improving medical school by engaging students. This study focuses on the first year of medical school, known as undergraduate medical education (Fig.1).

Training Phase	**Years**	**Level**	**Expertise**
Baccalaureate	1-4	Pre-Med	Layman
Undergraduate Medical Education	5-8	Medical Student	Novice*
Graduate Medical Education (GME)	9-11	Resident	Intermediate
Practicing Physician		Physician	Expert**

Figure 1. Levels of medical education. McCoy, 2013.
* Definitions of novice and an intermediate vary in the literature, but based on a description by Coderre et al. (2003) that 4th year students were novices, and the residents were still in training, I capped the novice category at medical school year 4, and inferred that residents were not experts.
** The literature varies on the definition of ‘expert’. Some suggest that physicians with more than 10 years of practice may be considered “expert” (Ericsson, 2004), while others (Coderre et al., 2003) imply that an expert is a specialist in a given discipline of medicine.

Students arrive to medical school equipped with four years of undergraduate baccalaureate “pre-med” training, but it takes a minimum of seven more years to become a fully accredited, practicing physician. Because medical education is such a lengthy process, it will benefit the field of medicine to validate learning methods that accelerate applied clinical reasoning skills. Through years of protracted studying, medical students can burn out or become passive learners if the learning environment does not reflect an interactive, multi-media approach. During clinical training, modern medical students must contribute strongly as members of clinical healthcare teams (Buring, Bhushan, Brazeau, Conway, Hansen, & Westberg, 2009). This implies healthcare students need to learn to collaborate well prior to encountering patients.

For the first two years of a typical medical school curriculum, students receive basic science instruction. During the second two years, students participate in clinical rotations (family medicine, internal medicine, obstetrics-gynecology, pediatrics, psychiatry, and general surgery), guided in their patient encounters by clinical instructors—called preceptors. Students are closely monitored during clinical encounters by preceptors to protect patient safety (Eva, 2005; Gawande 2009). To provide students with adequate preparation for clinical years, medical education experts propose several frameworks for rehearsing patient case scenarios in years one and two of medical school. These frameworks include case-based practice, simulation practice, early clinical experiences, and procedure checklists (Cooke et al., 2010; Gawande, 2009). Case practice helps students apply basic medicine principles to patient cases, often called “clinical vignettes.” These scenarios, when viewed on a computer screen, are known as virtual patient (VP) cases (Poulton, Conradi, Kavia, Round, & Hilton, 2009).

The trend toward virtual patient simulations (VPS). The American Association of Medical Colleges (AAMC) reported that 60% of medical schools are employing one type of screen simulation or another (Passiment, Sacks, & Huang, 2011). This trend toward VPS is not confined to the United States. Medical schools all over the world are developing them (Bland & Ousey, 2010; Cook & Triola, 2009; Ellaway, Poulton, Fors, McGee, & Albright, 2008). According to training experts, they are valuable and useful.

> Following the successful application of simulation technology for training pilots, it should be possible to use the simulators to provide basic training, as well as training for experienced pilots to react effectively in emergency situations. This development of training devices will make preparation in medical school and continuing education settings more individualized and effective, and will provide tools for expert performers to further enhance their levels of achievement. (Ericsson, 2004, p.S79)

VPS will allow first-year students to simulate managing complex clinical scenarios and demonstrate competency in clinical decision making.

The directionality of clinical reasoning. The medical education literature discusses the difference between novices and experts in terms of many aspects of reasoning. One key facet is the directionality of reasoning. According to Patel, Arocha, and Zhang (2004), there are three directions:: inductive, deductive, and abductive. Inductive reasoning is “forward thinking,” or reasoning from evidence to hypothesis. Reasoning experts point toward the strength of inductive reasoning strategy for many fields of inquiry, including medical diagnosis and criminal law (Carson, 2009; Patel & Groen, 1986; Prince & Felder 2006). Patel et al. (2004) characterize hypothetico-deductive reasoning (HDR) as “backward” thinking, first establishing a hypothesis and then confirming it through data collection. As defined by Patel and team, in real life, reasoning is abductive—a cycle of induction and deduction. The debate about which type of clinical reasoning is most effective continues, but in order to set the context at the national and international level, it is important to note most medical schools train using HDR (Groves, 2007). At this medical school, many professors teach diagnosis using “scheme-driven inductive reasoning,” a method which involves exploratory forward reasoning with the aid of decision tree flow charts (schemes). However, scheme-inductive clinical decision making also includes crucial tests that confirm the validity of each decision. This part of the process may be described as deductive.

The Local Context

The education site. The medical school under study, the School of Osteopathic Medicine (SOMA), was established in 2007. It supports a population of approximately 420 medical students (approximately 105 per cohort) and 65 faculty. In the first year, students study on the main campus. In years 2 through 4, they are distributed to eleven community health centers. According to its strategic plan (2013), SOMA's goals include increasing interactive, technology-enhanced learning experiences. In this environment, experimentation with innovative methods is encouraged, and faculty collaborate in team teaching and distance training projects.

The existing curriculum. There are several unique curricular features that bear upon the need for, the design, and the content of new VPS. The curricular features most salient to this study are listed in Figure 2.

Curricular Feature	Implication for the Innovation and Study
An integration of basic medical science and clinical science	Basic medical science comprises physiology, biochemistry, pathology, anatomy, histology, pharmacology and genetics. Clinical science comprises medical approaches, diagnostic procedures, laboratory tests, patient examinations, and treatment of patients. Most medical schools teach basic science for the first two years. This school integrates basic science content in the context of the clinical presentations years 1-2.
Scheme-driven reasoning	Most medical schools teach clinical reasoning using HDR (Groves, 2007). This school trains students to use forward, scheme-inductive reasoning. This philosophy influenced the design of the VPS in this study.
The clinical presentation model	Most medical schools do not employ this curricular approach. The education games and simulations produced reflect this methodology, which will be described in subsequent sections of this research paper.

Figure 2. Curricular features influential to the innovation and the study.
Note: See Appendix B for a more comprehensive matrix of curricular features.

To prepare first-year students for their clinical years, SOMA integrates basic and clinical science during the first two years. The clinical presentation model provides a specific, focused strategy for training first and second students in clinical diagnosis (Mandin, Harasym, Eagle & Watanabe, 1995). Let us say a patient presents to the doctor with a complaint such as "headache" or "regional back pain." This chief complaint is called a "clinical presentation." Within consecutive organ systems courses, the medical knowledge is encapsulated in modules for each of approximately 130 schemes. For example, the scheme "regional back pain" is taught during the Neuro-Musculoskeletal course. These CP schemes provide a road map for diagnosing the chief complaint. Instruction focuses on teaching students to diagnose a medical issue using a specific type of diagnostic flow chart, or ‘clinical presentation scheme’ (see Figure 3).

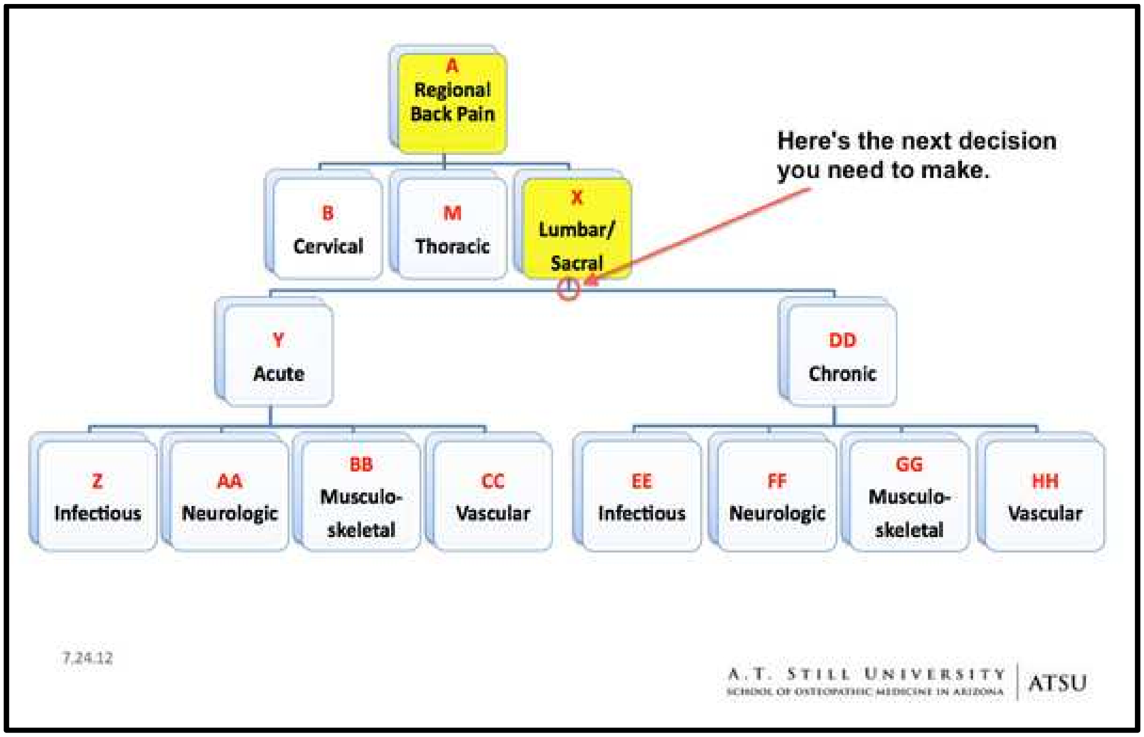


Figure 3. The Regional Back Pain Scheme—as depicted in a VPS.
Note: At the top of the scheme is a patient complaint: the way a patient presents to the practitioner. The student reasons down the scheme toward a diagnosis. Reprinted with permission (SOMA TEAL Team, 2013).

Using a flow chart as a map for a patient case, the medical trainee processes information and reasons his or her way down one or more paths of the scheme, moving from the complaint to a diagnosis, with consideration given to the patient history, physical condition, lab test results, as well as principles of basic science to move inductively toward increased specificity and a diagnosis.

OMSI case practice and clinical presentation schemes. This study investigates ways to enhance instruction for first year medical students. Scheme flow charts are also used in year 2, but second-year students are distributed to other sites. Hence, first-year students were more accessible. The first-year curriculum is intense: students attend more than thirty hours of large group classes and labs every week. In addition, these students meet weekly to study patient cases under the tutelage of “small group facilitators.” By practicing with patient cases, students construct problem-solving schemata for different illnesses (Mandin, Jones, Woloschuk, & Harasym, 1997). In order to become fluent at clinical reasoning, the literature suggests students need to run through a complex schema several times before it becomes an established, retrievable concept map (Merriënboer & Sweller, 2005). Requiring students to sort concepts using concept maps promotes their memorization (Anderson, Spiro, & Anderson, 1977; Daley, Shaw, Balistrieri, Glasenapp, & Piacentine, 1999). These suggestions from learning experts led me to believe that the students require more deliberate practice in order to integrate basic science theory with clinical science processes to solve cases successfully.

Technology-Enhanced Active Learning for Medical Education (TEAL-MED). This study generates from an ad-hoc academic curriculum workgroup called the TEAL-MED team, hereafter ‘TEAL team’. In December of 2010, the medical school approved the TEAL team to meet for weekly formal meetings as part of assigned work tasks to investigate the use of electronic games or simulation exercises for practicing clinical decision-making and patient care. A grant from the Health Resources Services Administration (HRSA, 2012) provided funding for a project involving game/simulation development. The dynamics of this team fits key descriptors of a Community of Practice (CoP) as defined by Wenger (1998), who describes a CoP as a team that meets on a topic of common interest, and through collaborative teamwork, evolves the project over time. The CoP designs tools, creates and stores knowledge, engages in practice through intrinsic motivation, developing a common culture. Over two years, the team has accumulated a certain amount of expertise and field jargon, culminating in a shared body of knowledge. This experience adds speed and synergy to problem solving.

TEAL team members. TEAL team members are faculty and staff healthcare education innovators interested in games, simulations, and clinical reasoning. These individuals are highly qualified to contribute content or review simulation modules and provide input from a variety of perspectives. Over the course of three years, this team has grown from eight members in 2010 to 15 contributors in 2013. Figure 4 lists the specialties of the TEAL team.

Local Core Members	**Members from Other Colleges**
Family practice, DO (2)	Internal medicine, DO
Internal medicine, DO	
Microbiologist, PhD	**Periodic Contributors**
Pediatrician, MD	Family Practice, DO (2)
OB/Gynecology, DO	Pharmacologist, PharmD
Bioengineer, PhD, MD	ITS Manager, ITS
Informatics specialist, MS	Internal Medicine MD
Curriculum Specialist, MTESL	
Technology specialist, ITS	
Physician’s Assistant MMS, PA-C	

Figure 4. 2013 TEAL team members.

In 2012, the team expanded to include members from other sites who meet with us via LifeSize™ (2012) video conferencing. The third section of Figure 4 lists other faculty and staff who receive meeting invites or who contribute periodically. As evidence of the expanding interest in this project, it became necessary to create a new website for the TEAL team and those curious about this work of designing games and simulations for healthcare.

Researcher’s role within the TEAL team. I am a founding member of the SOMA TEAL-MED team, currently serving as Assistant Chair, educational strategist, and active learning expert. In this role, I work collaboratively with the team chairman to plan the action agenda for the team, set out tasks, and organize weekly team meetings. My role involves organizing, developing and nurturing the projects of the team. During the period of the current study, I was responsible for developing the team as a high performing, productive CoP (Wenger, 1998).

Researcher’s role within the study. As lead investigator, I assumed full responsibility for planning, leading, and implementing each segment of the study: IRB approval, needs assessment, literature review, research design, competency framework, VPS production, field tests, design of the instruments, data analysis, results, discussion and conclusion (see Figure 5).

Procedure	Description
IRB Approval	ATSU-SOMA, ASU. July 2013
Needs Assessment & Problems of practice	Completed the landscape analysis, 2011-2012, two faculty surveys, 2011-2012, faculty interviews, 2012
Literature Review & Landscape Analysis	Completed the entire literature review, including virtual patient simulation case studies.
Research Design	Drafted and refined the research design. It was progressively reviewed by the TEAL team.
Competency Framework	Generated discussion and models leading toward the development of a competency framework. 2012
VPS Production	While I did not write content for the simulations, I managed software licenses, led faculty discussion in designing VPS, assisted faculty in improving them through iterative testing, and developed case guidelines. I worked with the simulation developers to modify the virtual patient simulation software.
Beta Trial & Field Test	Conducted Beta Trials in 2012 and a Field Test in 2013. Produced minutes from weekly TEAL team to document iterative cycles of implementation. August 2011-2014.
Exit Survey	Developed this first draft of this instrument. It was reviewed by the TEAL team in January 2013. I added additional items in August 2013 after the first field test.
Competency Task	Developed the Competency Task format based upon discussions with faculty, March, 2013.
Session Observation Forms	Developed the researcher and tutor observation forms. They were reviewed and improved by the TEAL Team. March, 2013.
Pre-Post Assessment	I organized the production of the pre-post assessments developed by the TEAL faculty, May, 2013 and November, 2013.
Data Analysis & Results Reporting	I transcribed and analyzed the qualitative data, worked with a statistics mentor to complete the quantitative analysis, and completed all sections of the dissertation.

Figure 5. Steps and procedures in the development of the research project.

The TEAL team served as a board of advisors regarding the study design and data collection instruments. TEAL faculty also prepared the simulation content and assessment items for the study.

Researcher's experience. For the past 30 years, I have been an adult educator, curriculum specialist, faculty trainer, and education researcher. Recent experience includes working at this medical school for four years, first in the clinical education department, then with the curriculum committee, and now in the faculty development office as assistant director. My current role is to support faculty and administration in their efforts to improve instruction in various facets: technological learning environments, lesson design, competency-based elements, tools of instruction, and interactive approaches— including educational games and virtual simulations.

Problems of Practice

The need for virtual patient simulations. As stated in the introduction, there is a need for medical students to practice virtual case scenarios prior to encounters with live patients. For this reason, medical colleges employ computer-based case practice with virtual patients (Passiment, Sacks, & Huang, 2011). However, until 2012, SOMA did not include VPS cases in its curriculum. This method is considered by many medical educators to be interactive and contextual. As a result, medical schools the world over are beginning to develop virtual patient simulations (Bland & Ousy, 2010; Cook & Triola, 2009; Ellaway et al., 2008). In terms of the clinical reasoning methodology, the simulations under development at SOMA employ scheme-inductive reasoning. Intriguing research suggests that scheme-inductive reasoning is more accurate for clinical diagnosis than deductive reasoning (Harasym et al., 2008; Patel et al., 2004).

Upon review of these trends, the TEAL team concluded that it would be worthwhile to introduce virtual simulations into the classroom environment. Faculty wondered whether engaging deliberate practice with virtual patient simulations would accelerate novice medical students' abilities in clinical decision-making by training them to solve patient cases using expert schemata. The process of developing a CPC case-based simulation for deliberate practice of inductive clinical decision-making required several cycles of experimentation and data collection. This process was influenced by design based research principles.

The need for deliberate practice. Learning sciences point to the importance of providing deliberate practice of target skills such as clinical reasoning (Bransford, Brown, & Cocking, 2000; Ericsson, 2004). Over the course of more than a hundred meetings of the TEAL team and from the published results of student and faculty assessments of the CP Curriculum (Schwartz, Hover, Kinney & McCoy, 2012), school faculty indicated that students needed more deliberate practice in scheme induction, as opposed to differential diagnosis through HDR. This was corroborated by research presented by SOMA students. In a 2012 presentation, one student reported that she would prefer not to use the differential diagnosis approach: “Only some faculty use inductive reasoning. I feel I learn better when they do use it. I don't want to use differentials to diagnose patients… how are we supported in using the schemes?” (2012). Furthermore, at the 2012 CPC Proceedings, a body of 40 medical educators from nine health care colleges discussed the need for students to construct their own problem-solving schemata through deliberate practice.

The need to standardize case practice. In their weekly schedules, OMSI students attend 30 or more hours of didactic presentations (lecture-based content), and look forward to interactive lessons during case practice in small group, led by tutors. Two hour sessions with tutors typically include three to four patient cases. The purpose of this type of small group meeting is to apply medical theory in the context of practice with virtual patient cases using scheme induction. About six master clinician faculty (physicians) oversee small group case practice as *facilitators* (hereafter referred to as tutors as per convention in the medical education literature). Groups of approximately ten students meet with a designated tutor in a breakout room weekly. During these sessions, the traditional method involves the physician tutor leading the students through three patient cases using a PowerPoint™ (PPT) projected on a large flat screen TV.

According to field notes, faculty interviews, and TEAL team minutes, the depth and quality of interpretive discussion and reasoning approach was not entirely standard between tutor-led sessions. The TEAL team surmised that it might improve small group practice if some VP cases were blended into the case practice curricula to standardize the depth of case analysis and clarify the forward reasoning approach to case analysis. This led to the decision that VPS with branching decision choices were worthy of field testing because they are interactive, experiential, and might entice students work more deeply with the case evidence. This level of engagement in problem-solving could benefit case practice in small group as one method of learning among many (TEAL team, 2012a).

The need to increase participation during group case practice. 2012 interviews with small group tutors indicated that faculty were guiding the students through the case using questioning, but as is common in small groups, each and every student within a group of ten students was not required to personally participate in every decision of every patient case. When students are not required to participate, they might expend less effort during group work even when they might work harder alone. This phenomenon is termed 'social loafing' (Dillenbourg & Hong, 2008) or 'free rider effect' – the passive participation of certain students within a group who reap the rewards of group effort (Piezon & Donaldson, 2005). Social loafing and free riding may be ameliorated by improving the structure of the lesson design (Dillenbourg & Hong, 2008). To accomplish this, educators should create a mechanism within the lesson that requires each student to participate and act. In summary, one reason for selecting interactive virtual simulations was to raise the participation quotient as well as practice scheme induction using branching cases. It is difficult to simulate branching patient case scenarios using PPT. Let us first describe the process of case-based learning with PPT.

The limitations of paper and PPT cases. Paper cases are packets that include details of a patient case. They are utilized for reference during case practice. In recent years, SOMA tutors focused the case discussion using a similar tool: a case PPT. The TEAL team described drawbacks of paper-based or PPT cases as follows. Instruction in this format is typically linear and non-branching. A branching case includes decision points that take students down diverse pathways. For example, if the student doctor chooses path A, the case continues with one set of consequences. If the student doctor chooses path B, there is a different outcome and a different set of consequences. To make lessons with PPT cases interactive requires a skilled facilitator who makes an intentional effort to involve all participants. Some faculty reported that it is possible to design PPT cases to allow students to try different branching options, but that is not how typical case PPT are utilized. Unlike VPS, the PPT medium does not have the capacity to collect and record student decisions. At this time in the development of the curricula, there exists no summative quiz, an exercise which counts for a grade, at the end of each small group session.

Problems of practice summarized. During the course of medical school, students encounter compressed curricula, and there is not extensive time for simulation practice. Students find their weekly case practice valuable for practice of clinical decision-making, but it could be improved to increase student participation, self-direction and self-assessment of competence.

Problem 1: First year medical students require more effective deliberate practice with patient cases in order to accelerate their ability to reason like expert physicians.

Case practice must be modernized to reflect authentic clinical practice. It should include multi-media in order to capture the interest of internet generation students (Johnson, 2006; Oblinger & Oblinger, 2005). It should be collaborative to train medical professionals who enter an era of team–based patient care (Buring, Bhushan, Brazeau, Conway, Hansen, & Westberg, 2009; Frenk et al., 2010). Based on studies reviewed, it appeared that first-year students would benefit from engaging, standardized, deliberate practice with case-based virtual simulations for clinical decision-making using scheme induction.

Problem 2: Currently, no scheme inductive virtual patient simulations are available on the market to purchase to augment the curriculum. Providing simulation experiences will serve to cement schemata for clinical reasoning, but the preferred method of clinical reasoning is scheme-induction. At the present moment, no scheme-inductive VPS are available for purchase. The educational benefits or consequences of VPS for clinical reasoning must be supported through research (Cook & Triola, 2009).

The Purpose of the Current Study

Primarily, this study investigates the utility of a virtual patient simulation for student deliberate practice of clinical decision-making skills, collaboration, and engagement. A sequential, triangulation mixed-methods design was used, a type of design in which complementary data are collected on the same topic. In this study, pre- and post-test measures, competency tasks, and survey instruments were used to test the theory of situated learning. Lave and Wenger (1991) describe the theory of situated learning as legitimate peripheral participation. Through simulation sessions, medical students participate legitimately (as trainees) but peripherally (under guidance) in the role of physicians, learning to safely care for simulated patients. Lave and Wenger further state that knowing a general rule does not ensure that an individual can carry it out in a specific situation. Engaging in collaborative healthcare team decision-making provides a bridge between personal cognition of a concept and its proper application in a real-world patient case scenario. The theory of situated learning supports the hypothesis that peer team sessions virtual patient simulation cases are more effective than traditional group instruction in terms of clinical decision-making skills, engagement and collaboration, controlling for instructional procedures, and participation for 108 first-year medical students at an undergraduate medical school.

The research frame. Following design based research (DBR) methods, the virtual simulations were field tested and improved (Edelson, 2002; Barab & Squire, 2004; Cobb, Confrey, diSessa, Lehrer & Schauble, 2002; Bannan-Ritland, 2002). This is the definition of DBR provided by Wang and Hannefin (2005):

> a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories. (p. 6)

According to Barab and Squire (2004), DBR

- is a series of approaches, with the intent of producing new theories, artifacts, and practices that account and for and potentially impact learning and teaching in naturalistic settings. (p. 2)

- is concerned with using design in the service of developing broad models of how humans think, know, act and learn.
- strives to generate and advance a particular set of theoretical constructs that transcends the environmental particulars of the contexts in which they were generated, selected, or refined. (p. 5)

Design research is useful when investigating the development or effect of an education innovation as opposed to action research that investigates one's own educational practice (S. Barab, personal communication, November 26, 2012). Lave and Wenger further state that knowing a general rule does not ensure that an individual can carry it out in a specific situation. Engaging in collaborative healthcare team decision-making provides a bridge between personal cognition of a concept and its proper application in a real-world patient case scenario.

Research Mini Studies	**Local Impact**	**Findings**
Faculty Needs Assessment Survey (SOMA, 2011)	Faculty identify three main competency areas for improvement: critical thinking, self-directed learning and professionalism	Faculty emphasis on critical thinking, self-directed learning and professionalism aligns with national competencies.
Faculty Survey: Educational Games (SOMA. 2012b)	Faculty indicated willingness to consider incorporating games in their instruction	Faculty are willing to experiment with this medium of instruction.
Student and Faculty Assessments of an Innovative Approach to Medical Education, (Schwartz, Hover, Kinney & McCoy, 2012)	These published studies confirmed the acceptance of the Clinical Presentation Curriculum (CPC) within the school. It provided a confirmation that faculty and students need training in scheme-inductive reasoning	The CPC model is valuable to students and faculty, but complex. More practice and faculty training is required to effectively implement this approach to instruction.
Computerized Simulation Games: Increasing Medical Student Skill in Clinical Decision-making (McCoy, 2011b)	30 Faculty and 40 students played and commented upon mobile app games. Voluntary participation in games and exit surveys did not render sufficient response rates.	Mobile game apps exhibit the potential to track decision-making skills. To gather sufficient data, it is necessary to implement games/simulations as required element in a monitored environment.

Figure 6. Relevant research mini studies conducted prior to the current study.

As noted in Figure 6, the TEAL team conducted several types of needs assessments. Some members of the team conducted a survey research study regarding the CPC, published in 2012. Finally, in 2012, prior education game research—using the game platform *Prognosis Your Diagnosis* TM (Medical Joyworks, 2011)—shed light on the viability of volunteer exercises with mobile application games outside of classroom practice and provided experience surveying the students regarding game design.

Phases of research. Following a DBR dissertation format (S. Barab, personal communication, November 26, 2012), I documented three cycles of VPS implementation for this project.

1. A beta trial, fall 2012, reported in the Appendix.
2. A field test, summer 2013, reported in Chapter 3.
3. A main study, fall 2013, reported in Chapter 4.

Research questions for the main study. The research questions for the final implementation (main study, fall 2013) are as follows:

1. For undergraduate medical students, year 1, to what extent does deliberate practice with virtual patient simulation improve skills in clinical decision-making?
    a) Student teams will demonstrate competency in clinical decision-making as measured by accurately completing 4 diagnosis performance tasks.
    b) Students agree that VPS are valuable for practicing clinical decision making.
    c) VPS are more effective than traditional case PPT's for teaching clinical reasoning skills as measured by a significant difference in mean gain between pre-and post-tests.
    d) VPS are more effective than traditional instruction with PPT's for improving clinical decision-making skills.
2. Which VPS mechanisms allowed the students to effectively make clinical decisions?
3. In which ways do VPS foster peer collaboration?
4. In which ways do VPS foster engagement?

5. Which design elements of this intervention need to be revised for the next implementation?

Introduction Summarized

In line with best practices in medical education, virtual simulations appear to be promising as useful tools for medical students. This study tests the hypothesis that inductive VPS develop clinical decision-making skills and foster student collaboration and engagement. The VPS were designed by the TEAL team, a CoP that encourages input from many stakeholders using a designed-based research approach. Literature searches, needs assessment, and several prior mini-studies supported the need for a new curriculum tool for practicing clinical reasoning. These VPS include mechanics for scaffolding scheme induction, following the Clinical Presentation Curriculum (CPC) native to the school.

This paper investigates how and to what extent VPS exercises provide collaborative, engaging skills-based practice in scheme-inductive clinical reasoning. It demonstrates VPS mechanisms that support decision-making and elicit rich, collaborative discussions. Many studies have indicated that simulations and games can provide effective deliberate practice, but the efficacy of a branching, recursive, inductive case-based simulation is unknown.

Chapter 2 - Literature Review

World View

This research will draw upon research traditions from several genres, culminating in a pragmatic worldview. The pragmatic stance involves gathering both objective and subjective evidence (Strudler & Wetzel, 2011). Health care professionals are typically trained in the post-positive scientific method, a research culture that is relatively objective and quantitative. Yet, this project required innovation and approaches consistent with a constructivist viewpoint, such as multiple perspectives and group processes. In order to facilitate the construction of knowledge about educational techniques, I infused collaborative, qualitative, ecological values of participatory research described by Creswell (2009).

The methodology of the innovation and the study design tests iteratively, and collects data that informs instructional design considerations following DBR. The DBR frame allows for a data triangulation mixed-methods approach. For example, it encourages mixing empirical data gathering techniques used by learning scientists (Bransford, Brown, & Cocking, 2000; Anderson & Pearson, 1988) and qualitative “in depth” inquiry refined by constructivists (Argyris, 1983; Gergen, 2009; Wenger, 1998; Vygotsky, 1978). Social constructivist methods employed included 1) seeking input for organizational innovation by listening to the authentic voice of the participants and stakeholders, 2) exploring environmental impacts, and 3) allowing for collective construction of meaning and consensus decision-making among the educator design team. The pragmatic world view is also useful in the realm of teaching medical students to employ inductive evidence gathering methods to learn and make clinical decisions (Patel et al., 2004).

Theoretical Perspectives

Overview

The pedagogy for this study blends two grand theories of learning (cognitive learning and constructivism). The design of the VPS is supported by cognitive learning theory, specifically medical cognition, inductive reasoning theory, schema theory, schematic diagrams, and cognitive load theory (Anderson et al., 1977; Clark, Nguyen, & Sweller, 2006; Patel & Groen, 1986). The collaborative, immersive simulation approach is supported by constructivism, including interactive learning, scaffolding, deliberate practice, self-directed learning, situated learning (Brown, Collins, & Duguid, 2007; Ericsson, 2004; Vygotsky, 1978) and virtual simulation theory (Barab et al., 2009; Gee, 2005). Innovation frameworks for this study fuse communities of practice theory (Wenger, 1998), leadership strategies (Fullan, 2011; Senge 1990), and DBR (Barab & Squire, 2004).

Theoretical Perspective 1: Cognitive Learning

Medical cognition. Medical cognition is a sub-category of cognitive learning theory. Approaches to medical cognition were developed over the past half century with many contributors (Elstein, Shulman, & Sprafka, 1990; Eva, 2005; Patel et al., 2004; Rimoldi & Raimondo, 1998). This body of literature applied cognitive theory to the assessment of medical performances based on the sequence of questions that physicians ask (Rimoldi & Raimondo, 1998). Further, it is applied to training physicians to reason and diagnose with better accuracy in clinical settings.

The topic of superior clinical reasoning skills has been debated for years in the medical education literature. One aspect of this body of theory, as evolved later by Patel et al. (2004), hypothesizes that novice physicians will diagnose with better accuracy using a forward reasoning approach. In *Thinking and Reasoning in Medicine*, these authors assert, “Medical cognition refers to studies of cognitive processes, such as perception, comprehension, decision-making, and problem solving in medical practice itself or in tasks representative of medical practice” (p. 2). In recent years, these researchers have hypothesized that novice physicians (medical students) make more accurate and thorough clinical decisions using inductive reasoning (Coderre et al., 2003; Patel et al., 2004; Prince & Felder, 2006). For this reason, the VPS innovation presented in this study requires inductive clinical reasoning.

*Scheme-inductive reasoning***.** In order to compare scheme-inductive and hypothetico-deductive diagnostic approaches, let us use a simulated scenario. Suppose an elderly woman patient presents to the medical student with a history of hypertension and a sudden onset of difficulty breathing. Using a hypothetico-deductive approach, the medical student must provide a differential diagnosis. This involves quickly reviewing key facts of the case, and then making an educated guess regarding the diagnosis. Is the patient's difficulty breathing life threatening? Is it caused by asthma, heart attack, lung cancer, congestive heart failure, tuberculosis, hypertensive crisis, or hundreds of other diagnoses? Next, using the differential diagnosis approach, the medical student selects one of these diagnoses and completes investigations to confirm it. This process is time-consuming, not to mention potentially expensive as the medical student attempts to rule out one diagnosis at a time.

Using a forward-reasoning, scheme-driven approach, the student considers patient affect, history, physical examination findings, and lab test results to reason down through the decision tree. First, is the difficulty breathing acute or chronic? Next, is the condition primarily cardiac or pulmonary? According to TEAL physicians (S. Brysacz, personal communication, February 19, 2013), there is an important difference in treatment for cardiac and pulmonary issues. The implication is this: When the diagnostic decision tree is provided by expert physicians, and the students learn to apply evidence and traverse the decision tree, then students may be able to make accurate diagnoses earlier in training than those using another method of training. Scheme diagrams help students understand the map of the entire process. An apt analogy might be football 'playbook.' At first a playbook is critical to a novice player. After a few months, all the coach needs to say is *"Play number 21,"* and the entire game plan instantly unpacks in the mind of the game player.

Since it is difficult for novice medical students to reach an accurate diagnosis with even many details about a patient, HDR can lead to errors in medical diagnosis and unsafe or unwarranted assumptions for novice physicians (Custers, Stuyt, & De Vries Robbe, 2000; Haeri, Hemmati, and Yaman, 2007). After several years in clinics, when medical students have encountered hundreds of patients, it becomes easier to arrive more quickly in the ballpark (general family) of the correct diagnosis. At the beginning, it is critical for students to receive deliberate practice in clinical reasoning though solving patient cases using a step-wise scheme inductive process, which involves collecting evidence at each decision point in the flow chart, and reasoning down the tiers of the flow chart (Harasym, Tsai & Hemmati, 2008).

Inductive clinical reasoning. As described earlier, according to Patel et al. (2004), there are three types of reasoning: inductive, deductive, and abductive. Inductive reasoning is "forward thinking", or reasoning from prior experience or evidence to a hypothesis. Deductive reasoning is considered "backward" thinking, reasoning from hypothesis to evidence (p. 5). Further, these authors describe that in real life, medical reasoning flows forward and backward in a cycle called "abduction." Diagnosis is an abductive, cyclical process of generating possible explanations (i.e., identification of a set of hypotheses that are able to account for the clinical case on the basis of the available data) and testing those explanations (i.e., evaluation of each generated hypothesis on the basis of its expected consequences).

Key study: Patel and Groen. In 1986, Patel and Groen published a landmark study supporting the use of forward reasoning for clinical diagnosis. These researchers studied the direction of reasoning used by expert physicians. Subjects included seven specialists in cardiology from McGill University. First, each subject read information about a patient case for 2.5 minutes. Then the subject wrote down as many details of the case from memory as possible. Next, subjects provided descriptions, in writing, regarding the pathophysiology of the case without reference to notes. Finally, each subject provided a diagnosis. Researchers analyzed the propositions in the recall text and mapped them to the pathophysiology propositions using flow chart diagrams. Researchers expected the pathophysiology to unite the case details the physicians could recall, as well as canonical knowledge (medical knowledge). These researchers found that for the four subjects whose diagnoses were correct, all of their reasoning followed a forward chain (pure forward reasoning), whereas experts with inaccurate diagnoses used some backward reasoning. The flow charts depicted in Patel and Groen's research resemble inductive trees. Researchers explain that the nodes at the end of the tree wait to 'fire" last because all of the antecedents must be fulfilled first. This forward reasoning tree mechanism results in a correct diagnosis.

Patel and Groen indicated that their results did not specifically contradict findings of prior investigators such as Elstein, Shulman, and Sprafka (1978) and Rubin (1975) who found evidence of hypothetico-deductive reasoning. Patel and Groen further note that backward chaining (deductive reasoning) seemed to be related to the difficulty of the case or in “empirical paradigms specifically requesting hypothesis generation” (p.108). A limitation of the study was the number of subjects, and the other mentioned by the researchers was regarding the post-hoc explanations for the case. Explaining the case post-hoc is not the natural manner in which physicians solve cases (step-by-step).

Key study: Kuipers and Kassirer. Patel and Groen (1986) reference a study by Kuipers and Kassirer (1984) which found a similar reasoning process of forward propagation. In this study, a second year resident was asked to think aloud to explain the process whereby the loss of protein causes edema in nephrotic syndrome. This explanation was transcribed. Each of the subject’s phrases (propositions) were analyzed and causal relationships diagrammed. In one segment, the subject described the hypothetical effects of salt intake resulting in edema (swelling). In order to build a conceptual model for this domain (Starling Syndrome) researchers built a computer simulation model from “textbook knowledge of the topic, the subject’s observations, and the computational requirements of successful performance” (p. 382). This resulted in a computational simulation model of the Starling mechanism. They hypothesized that the resident’s explanation would justify this formula: amt(protein,P)< normal = > amt(fluid,I)>.normal. Researchers were able to successfully align the explanation provided by the resident to the mechanism model. In their discussion, Kuipers and Kassirer inferred that in order to take in every single factor or possibility, computer models that depict phenomena tend to be much more detailed than that of a human’s. From their observations, they surmised that due to limits on working memory, a physician will use only those factors that appear to be particularly relevant, and therefore is able to constrict his attention to a smaller model.

There are four implications for the current study:

1. A forward reasoning strategy may generate better diagnoses for first year students when the cases are not too complex.
2. Clinical reasoning flow charts may be useful in year 1 because they provide a student with a model for sorting data and reasoning through a chain of causes and effects.
3. The human mind is only able to consider a finite number of possibilities at once. For this reason, clinical reasoning flow charts (schemes) may be useful because they narrow the range of diagnostic possibilities substantially each tier of the flowchart (G. Winfield, personal communication, April 5, 2013).
4. Studies employing the think aloud protocol using explanations that are elicited post hoc (once all the case details have been reviewed) have a limitation, since this process differs from what happens in real life. In real patient situations, the physician receives new data in progressive disclosure (first some details are provided and gradually the physician collects more evidence from investigations).

Deductive clinical reasoning. In their 2000 article outlining a new reasoning system, Custers, Stuyt, and De Vries Robbe explain that important research in deductive reasoning conducted by Elstein et al. (1978) revealed that the most positive predictor of diagnostic success is the quality of the diagnosis generated early. However, it is not easy for less experienced physicians to generate a quality hypothesis. Novice physicians exhibit these errors: 1) Inability to generate promising hypotheses. 2) Excessive data gathering. 3) Erroneous interpretation of cues. 4) Confirmation bias and overemphasis of positive findings. 5) Premature closure. 6) Excessive ordering of diagnostic tests (pp.294 and 295).

Key study: Taylor, Harasym, and Laurenson. In their 1978 research study, Taylor, Harasym and Laurenson studied the clinical reasoning skills of 64 medical students during a 20 hour segment of a reproductive course. Instructors scaffolded the content into ‘building blocks’ and each part of the lesson was guided by goals. At the outset of the unit, students were provided with a comprehensive study document with additional readings. Course materials also included a set of study questions, and students would practice comprehension by writing out responses. Using technology of the day, feedback in the form of the correct answer was revealed by “latent text”. Students also attended small group sessions led by tutors to participate in case simulations. The goal of these sessions was to assist students in learning diagnosis generation. Researchers assessed students after this course segment with a post-test that required subjects to recall facts, suggest diagnoses, and then test the diagnoses. The assessment included 20 MCQ questions (content recall) and two patient management questions (hypothesis and testing the hypothesis). After completing the first question, the student handed in the paper, and received the answer prior to completing the next. This prevented students from cumulative mistakes. Only forty seven of the 64 students satisfactorily formed and tested hypotheses (69%). Factual learning was successfully attained by 56 students (87%). Nearly all the students (62) filled out a questionnaire after the course, and 94% felt the course was helpful for improving problem-solving skills.

This study lends credence to the design of an independent study module VPS with support by case practice with tutors who are reviewing the same simulated case. The fact that the new forward reasoning VPS include scheme flow charts is supported by this study. It provides a model for further comparison studies deductive vs. inductive after the current study concludes.

Other medical reasoning experts do not agree that forward reasoning is superior, but reiterate that it is the level of experience (pattern matching to prior cases in memory) that distinguishes the superior ability of expert physicians to diagnose. For example, in Norman’s 2005 review of the literature on clinical reasoning, he indicates that the merit of forward reasoning is still in debate. In 2005, Eva concluded that it is important for students to become familiar with as many cases as possible as soon as possible because the more experienced the physician, the more accurate the diagnoses. Eva theorized that while the medical community is concerned that pattern matching is dangerous in novice physicians since they might miss relevant details about the context that alter how well the schema in memory match the particular case at hand, he feels this can be mitigated if students carefully list all of the evidence at hand, paying attention to the specific context. In response to this notion, one of the SOMA faculty indicated that while any quality physician, whether trained inductively or deductively would be thorough in patient investigations, it is difficult for first-year students to know exactly how to prioritize and use the data they collect from patients, and scheme diagrams help them select priority evidence (L. Lebeau, personal communication, July 15, 2013).

As may be evidenced above, while only a handful of clinical experts reasoning directly support the Clinical Presentation Model (Coderre et al., 2003; Harasym et al., 2008; Woloschuk, Harasym, Mandin, & Jones, 2000), many clinical experts support some elements core to the CP model, such knowledge encapsulation via flow charts, schemata, or illness scripts. For example, Rikers, Loyens, and Schmidt (2004) theorized that medical students first learn to condense or "encapsulate" knowledge and symptoms into universal medical concepts such as "sepsis" in the first few years of medical school, and then later learn to organize their thoughts into narrative "illness scripts". These are memories or prototypes for solving different case presentations in later years. A similar theory of "script" is described by Charlin, Boshuizen, Custers, and Feltovich (2007). As reported by physical therapists studying clinical reasoning, expert therapists use illness scripts and rely on their bank of experiences (Wainwright, Shepard, Harman, & Stephens, 2011).

In summary, while most medical cognition experts do not specifically cite or endorse scheme induction methodology, all agree that novice physicians need to build schema, scripts, or a repertoire of cases with which to pattern match. There is an ongoing debate about best practices in clinical reasoning, and this study will contribute findings to the literature on this topic.

Medical cognition and schema theory. For the purpose of this study, elements of schema theory (Anderson & Pearson, 1988) are applied to medical diagnostic reasoning in medical education (as opposed to medical practice). Taking a novice physician to the expert stage requires the instructor to assist the student in the construction of schemata, which are mental maps, or routines for solving the problems (Harasym et al., 2008). Novice professionals require opportunities to construct problem-solving schema, but after a year or two, the schema become innate and unconscious (Clark et al., 2006). Just as expert drivers will revert to auto-pilot based on an unconscious map, medical students must practice decision protocols and thought processes over and over until each individual skill along the way is bundled and the correct decision pathways are mapped (De Groot, 1978). In a 2011 study, van Kesteren, Ruiter, Fernandez, and Henson compiled studies in lesion and neuroimaging findings and explained a framework relating key brain regions during encoding, consolidation, and retrieval of information. The idea of activating the brain to stimulate deep learning is corroborated by Zull (2004), who emphasized that interactive tasks result in the growth of neurons and neurological connections. The design of new VP simulation exercises that rehearse and cement problem-solving schemata is intended to build and connect neural nets.

Schema theory and cognitive load. Simulation experts claim that there are specific ways to structure the simulations to allow students to maximize retention and connect with ideas (Mayer & Moreno, 1996). This approach suggests instructors design practice activities with cognitive load in mind. Schema allow novices to process large amounts of data like experts because they frame knowledge into system and chunks and connect them to theoretical principles (Merrienboer & Sweller, 2005). Further, these authors suggest that novices who do not have schema in place should not be required to problem solve a case with no guidance as this will unnecessarily tax their working memories. Students should first be provided with worked examples of cases. Next they should fill in gaps of knowledge using a worked example, and finally, try their hand at solving a case once the schema has been constructed. This suggests that educators should present 1) a worked example of a case solution, and 2) consequently provide independent practice allow students to test their ability to construct the clinical presentation problem-solving schema, and then 3) transfer these skills to a new case (new context). This 1-2-3 progression is ideal. The VPS provide a semi-guided independent practice. Applying the theory of cognitive load espoused by Paas, Renkl, and Sweller (2003), scheme-based practice during simulations should serve to cement the problem solving schema and bundle or encapsulate information concepts by creating concept linkages.

Inductive decision trees. Coderre et al. (2003) explain that clinical presentation flow chart 'schemes' reflect an organized knowledge structure for learning as well as a structure for diagnostic reasoning. They work like 'inductive trees' or 'road maps' to recreate the major divisions (or chunks) used by expert clinicians for both storage of knowledge in memory and its retrieval for solving problems. This scheme-inductive process differs from the usual inductive process (reasoning from the clinical data to a diagnosis) in one important manner. It is not simply forward reasoning toward a target hypothesis—reasoning with a single diagnosis in mind. The medical student faces decisions made at designated forks in the pathway. Sometimes the literature terms this as ‘eliminative induction’. According to Forber (2011), the trainee navigates down the inductive tree (scheme), which is organized into alternative causal groups, by conducting crucial tests, to exclude alternative groupings and adopt what is left. These tests may be based on an evaluation of symptoms, signs, or results of investigations, singly or in any combination.

The clinical presentation approach. Cognitive learning experts emphasize the need for students to connect ideas into schema (Anderson & Pearson, 1988; Dole & Sinatra, 1998; Merrienboer & Sweller, 2005). This pedagogy is consonant with use of virtual patient simulations to reinforce or help students construct medical problem-solving schema. When teaching medical problem-solving using the CPC, faculty employ graphic organizer flow charts described earlier as clinical presentation schemes. The use of flow charts is a time-honored strategy that supports scaffolding (Ausubel, 1980). Medical educators Harasym et al. (2008) recommend teaching novice physicians with the use of scheme-induction, reasoning from evidence to hypothesis using decision-tree flow charts. This method was proven in one study to render more accurate diagnoses (Coderre et al., 2003) as described next.

Key study: Coderre, Harasym, Mandin, and Fick. Coderre and associates conducted a landmark study in 2003. This study compared reasoning strategies among non-experts and expert physicians. Twenty non-experts (4th year medical students) and 20 physician specialists participated in this study. Participants were tested on their ability to diagnose four cases for four clinical presentations: dysphagia, diarrhea, nausea, and elevated liver enzymes. First, participants completed a written test with 12 questions: four multiple choice (MCQ) and eight extended-matching MCQ. Each of the four CP's related to three test questions. After completing the written test, participants were examined in a think-aloud format; during this exercise, subjects explained how they arrived at each diagnosis. Two constructs were assessed: diagnosis accuracy and cognitive process. Participants received a score of 1 for the correct diagnosis and a score of 0 for an incorrect diagnosis.

To assess the subject's cognitive process, two judges interviewed the examinees, who were asked to describe how each diagnosis was derived. Based on the examinees' verbal discourse for that question, the two judges determined the predominant diagnostic process used (categorization via scheme induction, hypothetico-deductive reasoning, or pattern recognition). When subjects used backward reasoning to rule out each diagnosis alternative, this was deemed 'hypothetico-deductive reasoning'. Determination that a scheme inductive diagnostic reasoning strategy was used occurred by analysis of the verbal discourse using modified propositional analysis. When subjects identified key phrases called "propositions" that linked categories of knowledge, this provided evidence for scheme-induction, e.g. 'categorization' or 'inductive reasoning'. These propositions mentioned in the Coderre study refer to branches of the clinical presentation schemes, and therefore this study was influential to our local faculty**.**

As reported by Coderre et al. (2003), experts achieved higher scores than novices. Second, the reasoning strategy utilized for a particular medical problem was significantly related to the odds of making a correct diagnosis. The greatest likelihood of diagnostic success was associated with pattern recognition (expert level memories of patient experiences). The second indicator of diagnostic success was scheme inductive reasoning. The ramifications for this study include a viable model for assessing student clinical reasoning processes as well as the supposition that inductive reasoning is superior hypothetico-deductive reasoning as an approach to medical diagnosis. The MCQ pre-and post-test items of this study were reviewed as a basis for item development.

Study limitations include questions regarding the validity of think aloud protocols. The findings of this study were analyzed by Eva (2005) who agreed in some respects, and disagreed in others. For both novice and expert, non-analytic or unconscious reasoning stems from prior experience with similar patient cases (pattern matching) to make probabilistic inferences about the current patient case. However, novices make more diagnostic errors than experts using the pattern matching method. In order to prevent novices from making diagnostic errors, Eva asserts that students simply need to be trained to list all the evidence before generating a hypothesis (2005). This emphasis on inventorying and prioritizing evidence influenced the development of some of the new pre- and post-test items used in this study.

Deliberate practice. According to Dhaliwal (2012), a renowned clinical diagnostician, the measure of competence for physicians is accurate diagnosis and gold standard patient care. To improve clinical reasoning, students require deliberate practice. This is defined as “a model of expertise development focusing effort and feedback on one arena until the gap between current and desired performance is closed” (p. 1473). During case practice, students rehearse scenarios with clinical decision-making over and over until they become fluent. Educators concur that deliberate practice (Ericcson, 2004; Opfer & Pedder, 2011) aids students in cementing concepts; ideally students should practice skills in multiple contexts or multiple cases.

Virtual patient simulations (VPS). Within the field of medical education, there is a growing interest in using interactive computer simulations. As described earlier, more than 60% of medical schools provide some type of curriculum using online virtual patient cases (Passiment et al., 2011). As evidence of the growing interest in this modality of instruction, the Medbiquitous Consortium (2011) explores ways to develop virtual patient cases and share them among medical schools all over the world. This organization derived a common standard of “case player” technology.

In 2011, St. George’s University in London published a study regarding their problem-based learning, branching case scenarios developed in Labyrinth™, a precursor to Decision Simulation. VPS cases were piloted with first and second year medical students. The study compared student preferences for linear (paper) cases versus branching (online) cases. MS1 students were exposed to their normal linear (paper) cases, as well as one (online) branching case scenario. Afterward, 29 MS1 responded to a survey, indicating that 75% would prefer to use branched cases in the future. In the second phase of the study, MS2 students were exposed to cases in both modalities (linear and non-linear). In a follow up survey after year 2, with 41 participants responding, 59% preferred online branching case simulations. In conclusion, while students missed being able to take notes with the linear paper cases, the majority of students preferred practice with online branching online cases (Poulton et al., 2009).

VPS and deliberate practice. Bryner, Saddawi-Konefka, and Gest (2008) suggest that students learn well using computer-based interactive modules. These researchers tested the efficacy of computer-based interactive modules in a randomized control study with 102 medical students. Both the experimental and control groups studied via traditional methods. The experimental group also accessed new interactive modules, while the control group did not. Despite a trend toward higher scores for the experimental group, researchers report no statistically significant difference between comparison groups on the final quiz. However, upon exit survey, the perceived concept difficulty was significantly reduced for those who studied with modules ($p < 0.001$) and number of hours spent studying with the modules increase ($p = 0.028$). This finding provides evidence that students might volunteer more of their study time to a VPS format exercise.

VPS and measuring clinical reasoning. The concept of measuring competencies is a time-honored strategy in military training (Tintera, 2003). Considering the potential of VPS for assessment is extremely relevant to this study. Feldman, Barnett, Link, Coleman, Lowe and O'Rourke (2006) write:

> The traditional method of evaluating a student's clinical performance on a ward rotation usually includes observations by, and interactions with, house staff and faculty. This method is necessarily subjective and prone to inter-observer variation, because different students will usually work with different house staff and/or faculty. (p.1385)

Achieving a valid method of evaluating students via screen simulations long distance would be a large benefit to the field of medical education.

Key study: Correlating VPS Scores with Course Grades. In a controlled study at Harvard Medical School's Pediatrics Department, clinical skills of year three and four medical students were assessed using an online virtual case based system called the "Clinical Assessment (CA)" (Feldman et al., 2006). A large group of medical students (411) were scored on these categories of reasoning: diagnostic assessment, effective collection of information, efficiency of collection of information, identification of factors important for diagnosis, and a justification of their selections.

This study found this correlation: at a score of 90% on the CA, virtually all the students received an honors category course grade. The exact number of simulations the students encountered is not described in this study, but the implication for this study is the advantage of this mode of learning for clinical education: Results from the Harvard study also revealed that students who ordered more laboratory tests did not necessarily arrive at a superior diagnosis to students who were more selective in the labs and examinations ordered. This last finding corroborates with TEAL team faculty views; during the first year, students should not be penalized for extra investigations (lab orders, imaging) because as a first priority, the students need to learn to collect a thorough history and organize evidence properly. TEAL team faculty introduced the skill of economizing investigations through cost meters in some of the beta trial sessions, but in discussions at team meetings determined that these skills can and should be emphasized with more attention to detail in subsequent training years, and will become especially salient as students encounter the realities of procedures and their costs in the process of treating patients.

Key study: Measuring the effect of VPS. In a recent study, a Swedish research team (Botezatu, Hult, Tessma, & Fors, 2010) observed differences of undergraduate medical student performance on Internal Medicine course exams. In an experimental design study, four cohorts of students (216) who studied using VPS scored significantly higher on examinations ($p < 0.001$) than those in a control group who studied using traditional methods such as lectures and mannequin simulations. Researchers reported results from a number of different treatment groups "with the effect size ranging from 1.1 to 2.9" (Botezatu et al., 2010, p. 848). The implication for the current study is that there is a potential for VPS to achieve measurable gain in skills acquisition. The question is this: how many hours did individual students study with VPS to achieve this effect? The authors only describe the sessions as being 45-60 minutes long, with the trial taking place over a four month period.

Key study: Assessing competencies. Games expert Valerie Shute has published probabilistic methodology regarding the concept of 'stealth assessment' of competencies through games (2011). In their landmark paper "Conceptualizing Frameworks for Modeling, Assessing, and Supporting Competencies in Game Environments" (2010), Shute, Masduki, and Nonmez described this method, which is termed Evidence Centered Design (ECD). ECD employs the use of Bayesian networks (Earman, 1992) toward accurate inferences of competency states. Shute and colleagues emphasizes the need to identify key competencies such as systems thinking: "the ability to understand the relationships between elements in a given environment" (2010, p. 142). "Using the ECD framework, the assessor (a) defines the claims to be made about students' competencies, (b) establishes what constitutes valid evidence of the claims, and (c) determines the nature and form of tasks or situations that will elicit that evidence" (p. 139). To our knowledge, the theory has not yet been applied directly medical education simulations or medical education game data, but it outlines a very potentially useful process for triangulating study findings. The TEAL team identified a set of core competency areas and used this competency framework in defining the scope and goals of the game content. Each target competency (key decision in the exercise) is supported by a group of specific evidence analysis tasks.

There are possible negative connotations of the term "stealth assessment," and therefore in a team meeting in 2011, the TEAL team seemed more philosophically inclined to make students aware when exercises will be analyzed and treated as assessment results to isolate skill areas for improvement. If the students are quizzed or assessed formally via the simulations, they will be made aware of the fact. This philosophy reflects current thinking.

The implications of these various studies point to the potential for a study to be conducted using a set of VPS as educational practice intervention, using a post-test model.

Following the Shute ECD framework, the design of the VPS should reflect competencies and list the tasks that elicit the evidence of competency attainment.

A summary of cognitive learning theory as it applies to this study. In recent years, researchers have hypothesized that novice physicians (medical students) make more accurate and thorough clinical decisions using inductive reasoning (Coderre et al., 2003; Patel et al., 2004; Prince & Felder, 2006). For this reason, the new VP simulations feature exercises involving inductive reasoning.

A review of the literature reveals that while not all experts support scheme inductive method, all are cognizant that novice physicians need to build schema, scripts, or a repertoire of cases with which to pattern match (Charlin et al., 2007; Eva, 2005; Harasym et al., 2008; Norman, 2005; Wainwright et al., 2011). For this reason, the design of new VPS exercises affords learning spaces for students to rehearse and cement problem-solving schema. By completing a series of virtual patient cases, the student builds a repertoire of patient encounters that enables pattern matching.

Using the scheme inductive reasoning method (Harasym et al., 2008) students are presented with clinical decision choices at the forks in the decision tree. The organizational structure of the decision tree, or 'scheme', proceeds from alternative causal groups. To navigate down the scheme tree, the student completes crucial tests, to exclude some choices and adopt others. In the Coderre study (2003), researchers determined that that the most effective strategy is pattern matching, followed by scheme-driven forward reasoning. This design of the VPS supports the forward reasoning approach. The MCQ pre-and post-test items from the Coderre study were reviewed as a basis for item development for the current study. Cognitive load theorists Paas and Renkle (2003) corroborate that scheme-based practice during simulations should serve to cement the problem solving schema and bundle or encapsulate information concepts by creating concept linkages.

Taken together, these specific sub-theories of cognitive learning (schema theory, forward reasoning, scheme inductive reasoning, pattern recognition, evidence sorting, and cognitive load theory) provide a strong framework of personal cognition. They point to best practices for teaching medical students to process, store, and retrieve information as well as make clinical decisions. However, there is also ample evidence that knowledge is situated and co-constructed. For this reason, this study draws upon some facets of the theory of constructivism.

Theoretical Perspective Two: Constructivism

Overview. Constructivism is the second major pedagogical theory pertinent to this study. Social constructivist philosopher Gergen (2009) explains that the development of the constructivist stance is a continuing dialog, but implies that its basic tenant is "together we construct our worlds" (p. 2). According to Gergen, this means that what we learn from the world depends on how we approach it, and the manner in which we approach it depends on the social relationships of which we are a part. In terms of instruction, according to Kivinen and Ristela (2003), the theory of constructivism was developed by education reformers such as John Dewey, Jean Piaget, and Lev Vygotsky (1978). Kivinen and Ristela explain that constructivists do not view the learner as simply reacting to external stimuli, but celebrate active learning and participation. Through group activities students acquire knowledge through interaction with the environment and others. According to Vygotsky, learning is optimized in a context, and students scaffold more knowledge through discussions and activities with instructors and other classmates. Students co-construct meaning through personal experiences by working through the "activities of a community" (Mann, 2011; Vygotsky, 1978; Gergen, 2009). Lave and Wenger (1991) call this 'situated learning.' These authors define the concept of 'legitimate peripheral participation" described as the process through which trainees gain orientation to the professional culture by participating in activities of the practice through a limited, mentored (peripheral) apprenticeship, gradually assuming more responsibility over time. The VPS described in this study provide safe virtual learning environments, allowing medical students to gradually increase their ability to manage clinical cases.

Because medical education prepares students for professional practice including teamwork, Mann (2011) asserts that future models of medical education will evolve toward incorporating constructivist frameworks, including situated learning and social activities. “More recently, post-structuralist understandings offer an approach to knowing that acknowledges complexity, supports the plurality of meaning, and encourages innovative ways of knowing” (p. 121). In higher education, there is a trend toward emphasis on active learning, collaboration, and peer discussion (Cullen et al., 2012; Wieman, 2004).

In summary, the theory of constructivism supports collaborative case practice with virtual patient simulations as a method of preparing medical students before they interact with real patients through situated learning. This study focuses on sub-theories of constructionism: situated learning, schema theory, collaboration, active participation, scaffolding, and deliberate practice.

Construction of meaning through situated learning. Clinical decision-making simulations require the students to interact within a specific situational context to interpret (make meaning of) patient data. Simulation games are also valid as learning experiences according to the theory of situated cognition that generates from constructivism. For example, the simulated experience of assuming the role of a physician is one example of legitimate peripheral participation within the professional community of physicians (Lave & Wenger, 1991), meaning that students will participate in practice to safe, limited extent, under the guidance of their physician tutors (physical or virtual). According to Gee (2005, 2008), virtual simulations provide professional practice in decision-making in the heat of an authentic context such as military training or business operations. These electronic simulations also provide a competency-level assessment of skills because in order to complete the simulation and win the ‘game,’ the player must successfully solve the problems posed. In this regard VPS support the student in constructing problem-solving schema.

Constructivism and schema theory. While schema theory is categorized by some under cognitive science (Van de Sande & Greeno 2012), according to Duckworth (2006) constructionists such as Piaget use this term to talk about the way people develop mental models. Therefore affordances such as flow charts work to support the construction of problem solving schema within the minds of the students (Clark et al., 2006). While the end goal is for schemata to crystalize in the learner's mind, screen-based flow charts act as training wheels tools for novice physicians, useful for constructing a problem-solving routine. They are not 'terrain maps'; students will learn the terrain of patient case encounters from experience with specific cases. In a collaborative setting, these screen-based flow charts provide a 'common perspectival frame' (Van de Sande & Greeno, 2012)—student to student and faculty to student.

Student construction of schema. Establishing conceptual frameworks for case problem solving is particularly pertinent in the first few years of medical school, until the schemas are internalized. The concept of schema construction for problem solving is relevant because the virtual simulations developed by the TEAL team specifically require the students to process evidence at each key decision point in the case. Part of the process of schema construction is reified in student concept mapping work (Van de Sande & Greeno, 2012). Using this method, student doctors are required to show their work step-by-step, moving down a scheme decision pathway in solving story problems called clinical vignettes (see Figure 7).

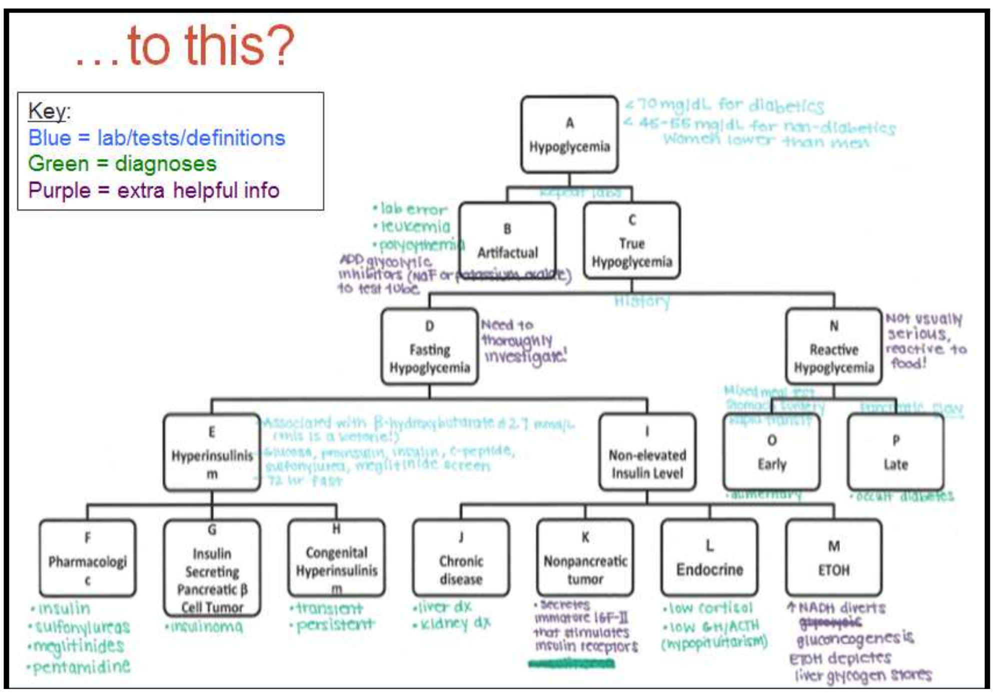


Figure 7. A student's annotation of a clinical presentation scheme.
Note: A first year medical student shows her work, constructing a mental map by adding in the evidence required to make decisions at each node in the scheme. Permission granted for reprinting (Ferrari, 2012).

In the course of a given VPS lesson, students are collaborating on decisions, working their way down the scheme pathways. Students are personally and collectively constructing meaning as they attach theoretical concepts and lab values to the nodes and decision points of the flow chart.

Self-directed learning. In medical education, practitioners refer to "self-directed learning" as a means of making students more responsible for their own learning. Mazmanian and Feldman (2011) explain that using this theory,

1. teachers act as facilitators rather than as sources of content;
2. learners are involved in selecting learning resources and strategies, and
3. learners are involved in self-assessment of learning outcomes. (p. 324)

This theory supports the application of learning tools that allow the student to guide themselves through the lesson at their own pace, and depend less upon the instructor, such as an online simulation or game. In the course of the simulation, students complete the problems presented for fun, hardly aware that they are gradually building skills along the way. In this way, virtual simulations scaffold learning. DeBilde, Vansteenkiste, and Lens (2011) assert that self-directed learning results in intrinsically motivated participation and better learning outcomes.

Scaffolding. As described by Sherin, Reiser, and Edelsen (2004), in its original use, scaffolding is a term describing an instructional strategy; when students cannot complete a task or project alone, scaffolding is the assistance they receive from a mentor, tutor, or peer. Furthermore, students will gradually be able to complete these tasks on their own as scaffolding subsides in a process called "fading" (gradual removing of scaffolds). Following from both the constructivist and cognitive science philosophies, learning theory experts confirm that scaffolding learners from the novice to the expert stage involves teaching students to actively construct schemata, and refer back to larger, foundational theoretical concepts (Aufschnaiter, 2003; Bransford et al., 2000). SOMA VPS provide scaffolding through three main mechanisms: scheme concept maps, rich feedback and required student collaboration. These mechanisms will be described in Chapter 3.

Peer collaboration. Constructivists argue that students co-construct meaning; concepts and connections become clear when students restate facts, ask questions, articulate reasoning, and are tasked with achieving consensus on decisions. Small group facilitation specialists Westberg and Jason (1996) indicate that peer learning is important in the development of healthcare professionals because experts can forget the mindset of novices, who often explain concepts to peers in simple, experiential terms. This theory is consonant with Vygotsky's (1978) notion of scaffolding. Peers offer assistance when a new concept lies just outside the learner's ability or immediate grasp (zone of proximal development).

In the healthcare field, team collaboration is increasingly emphasized due to the new paradigm of inter-professional discussions that occur during patient care among teams of physicians, nurses, physical therapists and legions of other specialists (Buring et al., 2009; Frenk et al., 2010). A recently published set of national interprofessional collaboration competencies provided the collaboration theory for this study. This report, entitled *Core Competencies for Interprofessional Collaborative Practice*, lists essential skills recommended for this generation of healthcare professionals (IPEC, 2011). According to the TEAL team (2013), whether or not students indicate that they value peer team work, this generation of medical students must learn to collaborate in order to provide optimal care. For example, one of the target IPEC competencies for the teamwork element of the VPS learning exercises in this study is to "express one's knowledge and opinions to team members involved in patient care with confidence, clarity and respect, working to ensure common understanding of information and treatment and care decisions" (p. 23).

Certain IPEC competencies seemed particularly essential for first year medical students. Four key attributes of collaboration were chosen for this study and intervention. Three were from IPEC: 1) respectful communication, 2) consensus decision making, and 3) full participation of all team members. The fourth is not from IPEC, but reflects the theory of scaffolding described earlier: 4) clarification of conceptual muddy areas.

Engagement.

Interest. Undergraduate medical education is in the process of moving toward cognitively engaging, experiential learning (Tagg, 2003). New media literacy research indicates that the current internet generation student population is more fully engaged by electronic media and audio-visual stimulation (Johnson, 2006). For the purpose of this study, one aspect of engagement is labeled “interest”. Interest is related to the importance of providing a variety of learning activities to avoid burn out and boredom. Game expert Prensky (2001) describes the beneficial effect of “play” in work contexts as follows:

> People play at work to seek competence, stimulation, challenge, or reinforcement: playful tasks foster creativity. If the playful tasks are new ones, they will put much effort into learning them and exploring them, usually trying to control their own learning. (p. 5-9)

Following best practices outlined by (Oblinger & Oblinger, 2005), providing cognitively engaging playful tasks during medical school should serve to break up the monotony of the study week. This approach considers the learning preferences of this generation of tech-savvy medical students, who grew up in an era of video games and group activities.

Relevance. Relevance is a sub-theme of interest. Learner motivation experts Eccles and Wigfield (2002) explain that school is more effective when it is relevant to (or aligns with) future professional goals. This notion is corroborated by Bilde, Vanteenkiste and Lens (2011) as well as Lave and Wenger’s (1991) theory of situated learning. These researchers indicate that adults are more intrinsically motivated to complete learning tasks when they understand their full value and relevance to academic, workplace, or personal goals. One goal of SOMA first year medical students is to competently apply medical theory to medical practice. This will allow them to succeed as an effective healthcare team member during clinical rotations in years 2-4. The VPS were designed to support this goal.

Flow. Another facet of engagement is called “ flow” (Admiraal, Huizenga, Akkerman & Dam, 2011; Eccles & Wigfield, 2002; Schiefele & Raabe, 2011). Engagement is too broad of a concept to measure, but the variable *flow* allows educational researchers to operationalize specific attributes of engagement. Admiraal et al. define ‘flow’ as a “state of concentration, interest and enjoyment" and assert that even demanding, skill-based activities can promote flow because these activities provide satisfying interactions that scaffold students through a series of difficult tasks. Furthermore, these researchers explain that flow may be measured in two ways: by self-assessment, meaning that the students fill out a survey, or by instructor observation of the learning experience.

Key study: "Flow" and "concentration". Following the research of Schiefele and Raabe (2011), engagement may be measured by the participant's self-reported degree of flow (absorption in the activity), and concentration on task. In 2011, a study of 89 undergraduates was used to validate a set of flow survey items. Study participants completed several intelligence tasks from Ravens' Progressive Matrices. Researchers created a pool of 10 items (five flow, five concentration) and participants were asked to rate tasks on a 5-point scale. Using factor analysis, the researchers validated 9 of the 10 items. This research resulted in valid "flow and concentration" items that held internal consistency over four experimental trials (.76 - .81). Authors state, "Taken together, the findings suggest that inductive reasoning tasks represent an appropriate tool for experimental flow research" (p. 441). Their validated assessment tool "Measures of Flow Experience and State Concentration" is provided in Appendix D. These items were used in the Field Test exit survey instrument, used to measure student impressions after they participated in learning via VPS, and consequently four were chosen for the main study.

A summary of constructivism as it applies to this study. This paper asserts that the constructivist theory of situated learning supports VPS as an effective instructional modality for preparing and assessing the clinical reasoning skills medical students before they interact with live patients. VPS provide safe training experiences in which novice student doctors cannot inadvertently harm live patients (Ziv et al., 2006). Students take responsibility for working through the case under the guidance of written feedback developed by experienced clinicians. This process conforms to the process described by Lave and Wenger (1991) termed "legitimate peripheral participation" that enables students to gradually absorb a professional culture and practice by guided constructive activities. VPS allow students to engage in focused practice or rehearsal of a patient scenario until they achieve their own measure of success or skill levels set by the school. This method is supported by novice to expert theorists such as Ericsson (2004) and Dhaliwal (2012). By rehearsing problem solving routines, students construct problem solving schemata (Clark et al., 2006). This process is aided by content scaffolding and mechanisms built into the VPS, such as flow charts, feedback, student agency, and peer- collaboration.

One primary goal of the VPS is student engagement. This study specifically focuses on two engagement sub-components, flow and interest. For the purpose of this study, flow indicates the level of absorption in the activity. Learner-centered methodology (Cullen et al., 2010) indicates being sensitive to the habits, attitudes, and needs of the students. This paradigm of learning advocates relevant learning episodes as well as fostering independent learning. It urges higher learning educators to avoid pure lecturing in favor of active learning, especially technology-enhanced learning (Kereluik et al., 2013). The construct of relevance was also added to this study for a second reason; in personal conversations with the SOMA faculty of medicine, they asserted that the use of educational games or VPS should be relevant and sensitive to the needs of students for passing the medical boards or course exams. Aside from the study's education theoretical frame, an innovation implementation framework bears discussion.

Theoretical Perspective 3: Innovation Implementation Strategies

Overview. This paper studies the implementation phase of a greater educational games initiative. In its conception, development, and implementation phases, several theories influenced the initiative's process, trajectory, and measures of success. These theories included: 1) Community of Practice theory (Wenger,1998), 2) Fullan's (2011) leadership principles for implementing innovations (2010), and 3) strategies salient to integrating an innovation into the ecology of a learning organization (Barab & Squire, 2004; Cobb et al., 2002; Senge, 1990). The following section reviews these theories as they apply to the project.

Establishing a Community of Practice (CoP). One of the foundation strategies for developing a successful innovation is a steering committee or a CoP. Described by Wenger (1998), a CoP employs collaborative strategies to build the support base for simulation game development. The literature describes the most innovative CoP are creative and synergistic, whether they are termed ‘value-driven networks,’ ‘passion communities,’ or ‘high performing teams” (Gee & Jenkins, 2011; Woolley, Chabris, Pentland, Hashmi, & Malone, 2010). Participatory design-based research involves collaboration, consensus, and knowledge construction. In a team, the collective intelligence may be enhanced by equitable contributions and the emotional intelligence of group members–as described by collective intelligence theory (Woolley et al., 2010). By supporting a contributory climate among TEAL team members, I encouraged them to pose questions, review evidence, test design iterations, and arrive at consensus.

Fullan’s key principles for innovation implementation. In terms of the workflow of project management, during weekly TEAL meetings, I followed several of Fullan’s (2011) key principles for implementing an innovation:

1. Relationships. Using the ‘Relationships first’ strategy, an educational innovator nurtures team member relationships. For example, it is important connect with team members daily and address what they need in order to complete their tasks.
2. Planning. The ‘Beware of the fat plan’ strategy counsels leaders not to overwhelm team members with an elaborate plan. Instead, the organizers should communicate clear, concrete steps, and core aims. Each week, I posted the team meeting agenda and requested input so that everyone knew the plan and could arrive ready to work through the project tasks. In 2011 and 2013, I led the team in visioning sessions to develop long term goals.
3. Test drive. The TEAL team followed Fullan’s principle: ‘Behavior before beliefs.’ This involved providing faculty outside the TEAL team opportunities to experience the new learning tool instead of asking them to believe in it conceptually. All of the faculty received VPS accounts and were invited to review new simulations online. This method is consonant with a situated learning theoretical frame.
4. Implementation disposition. The next strategy is entitled, ‘Honor the implementation

dip.' The implementation dip is the period of negative gains in the first phase of implementing an innovation. It is important to encourage fellow education innovators and classroom instructors through this rough period. The TEAL team sought input from stake holders during the beta trials. Even though student and faculty feedback was positive, during the first two trials, a few technology issues occurred. For this reason, the implementation dip resembled a busy, turbulent period as the new technology came online. Gradually the team gained capacity, the new tools improved, and the VPS were accepted into the courses. Over the span of the 2010-2013, the curriculum evolved to integrate the new instructional method, as evidenced by more than 85 games or simulations (of all genres) implemented in courses or faculty trainings.

5. Communication. Fullan's philosophy is that communication is important, and especially during the implementation dip. It was important to work closely with faculty and staff to implement the beta trials smoothly, and to act upon feedback from the small group tutors and students in order to improve the content and delivery of the VPS.

DBR Iterative improvement cycles. Following DBR methodology (Barab & Squire, 2004; Cobb et al., 2002), I employed an iterative process of revision to improve the innovation. During the fall of 2012, I set up beta trials, which were cycles for testing the new curriculum tool in the classroom. Using data I collected and analyzed after each implementation as an evidence base, the TEAL team achieved consensus on design refinements.

Systems ecology. From an educational technology design perspective, the design-based research process encourages sensitivity to the total school environment and works toward constructing a sustainable plan for supporting the new technology within the system of the school (S. Barab, personal communication, March 26, 2013). The buy-in for implementing these VPS within the existing curricular framework involved frequent communication between TEAL team faculty, small group tutors, and other course directors. Modeling an ecological, participatory frame of research involved seeking input from stakeholders. For example, I requested faculty and students to provide feedback on aspects during development. Small group facilitators provided feedback throughout the study. Students provided opinions through exit surveys. Over the course of two years, the project, small groups were improved, and the curriculum underwent changes.

Systems based thinking. An ecological approach is consonant with systems based thinking suggested by 'learning organization' expert Peter Senge (1990). Applying Senge's strategy for facilitating the acceptance of the VPS involved explaining the project to individual stakeholders and administrative leadership to engender trust and buy-in. Winning strategies for gaining street credibility and acceptance included:

- providing multiple faculty development workshops on games and VPS,
- allowing faculty to try the simulations,
- working with course directors to embed activities inside courses,
- fitting VPS into smaller time frames (half hour activities),
- gaining approval through the various curriculum workgroups,
- preparing and training the small group tutors,
- explaining the evidence base for VPS,
- seeking student and tutor feedback, and
- reporting results at faculty meetings.

As a result, the process of implementation was transparent, conciliatory, and collaborative.

A summary of innovation implementation theory. This innovation project is one element in a wider initiative at SOMA termed "Technology Enhanced Active Learning for Medical Education." This paper summarizes elements of the VPS development, implementation, and assessment of their effectiveness. Three major theories drove the implementation and testing of this innovation. First, CoP theory (Wenger, 1998) guided the formation and collaboration within the steering committee. Second, Fullan's (2011) leadership principles enhanced communication regarding the project and its goals. Third, an ecological approach eased integration within the existing medical school curriculum (Barab & Squire, 2004; Cobb et al., 2002; Senge, 1990).

Literature Review Summation

In conclusion, a preponderance of evidence that supported the need for standardized case practice tool: specifically a flow-chart-driven, branching case scenario meets the needs of first-year students at this education site. VPS provide opportunities for practicing clinical decision making in a participatory, collaborative format. Figure 8 condenses the key concepts into findings.

Concept	Literature Findings
Inductive reasoning	Many researchers conclude that inductive reasoning is superior to hypothetico-deductive reasoning for novice physicians. Medical students will make more accurate and thorough clinical decisions by gathering evidence and applying the evidence using forward, inductive reasoning. VPS have been successfully used by other medical schools to teach clinical reasoning. <u>Study implications:</u> The VPS cases employ evidence gathering and forward reasoning. This study focuses on investigating student gains in critical thinking skills, specifically forward reasoning. More evidence is needed to determine whether a scheme-inductive VPS is more effective than traditional instruction for increasing medical student decision-making skills.
Pattern matching	Many medical cognition experts including Coderre and Mandin concede that expert diagnosticians pattern match. While not all medical cognition experts support the scheme inductive method, all recognize novice physicians need to build schema, scripts, or a repertoire of cases with which to pattern match. <u>Study implication:</u> provide students with repeated virtual patient experiences so they can build a vivid repertoire of cases.
Scheme induction	Some researchers believe that scheme inductive reasoning assists medical students in learning to make accurate clinical decisions. To navigate inductively down the scheme tree, the student completes crucial 'tests', at each branch to make a clinical decision. <u>Study implication:</u> The VPS cases employ a scheme inductive approach.
Clinical Presentation Curricular (CPC) Approach	This school's curriculum employs the CPC approach in an effort to accelerate the novice physician's ability to make clinical decisions. <u>Study implications:</u> The VPS cases employ a CPC approach. The Coderre study provided multiple choice questions that inspired the development of new assessment items. The VPS employ a branching, recursive design, matching the CP method.
Schema Theory	Following schema theory, the scheme inductive method aids students in constructing schema useful for problem solving in clinical scenarios. <u>Study implications:</u> The study will test the efficacy of the VPS mode of instruction to improve the student's ability to transfer schema developed through practice to a test case.
Cognitive Load Theory	Scheme-based practice during simulations should serve to cement the problem solving schema and bundle or encapsulate information concepts by creating concept linkages. <u>Study implication:</u> The VPS should be designed to streamline knowledge into chunks and tasks that effectively manage the processing of large quantities of information.

Figure 8. *Literature review: Theories of cognitive learning.*

Constructivist andragogy supports the simulation lessons because they employ a situated learning approach (Lave & Wenger, 1991; Vygotsky, 1978, Gee, 2005). Figure 9 provides key findings from the review of literature on these theories.

Concept	**Literature Findings**
Situated learning	Constructivists endorse situated learning (active, contextual learning). Study Implication: Virtual simulations may be leveraged to approximate authentic workplace conditions.
Legitimate peripheral participation	This theory states that students gradually learn a professional culture and practice by mentor-guided constructive activities. Study Implication: VPS allow students to engage in legitimate peripheral participation. They provide safe training experiences in which novice student doctors cannot harm live patients or themselves.
Deliberate practice	To take a novice physician to the expert level requires deliberate practice. This concept translated to patient care requires rehearsal of a patient scenario until students achieve skill fluency. Study Implication: VPS allow students to engage in focused practice.
Scaffolding mechanics	Scaffolding mechanisms built into the VPS aid schema construction. Mechanisms include scheme flow charts, feedback, and peer collaboration. Study Implication: It is hoped that these mechanics will create a superior learning experience to traditional, linear PowerPoint instruction.
Peer-collaboration	Social loafing is the tendency of certain students to expend less effort during group work even when they might work harder alone. There is also a behavior characterized as the “free rider effect” – the passive participation of certain students within a group who reap the rewards of group effort. This dynamic may be ameliorated by improving the structure of the lesson design. Beta trials indicated that the optimal size of student group was 3-4 students. Constructivists argue that students co-construct meaning: concepts and connections become clear when students restate facts, ask questions, articulate reasoning, and are tasked with achieving consensus on decisions. Students benefit from discourse with peers who bring a different perspective or more experience. Modern theories of healthcare teamwork emphasize the importance of collaboration among healthcare professionals. Study Implications: It was important to add the element of collaborative teamwork in the VPS lesson design, to limit the number of students per group to four, to observe team dynamics during the field tests to ensure all were participating, and to survey the students regarding their views on the value of team consensus.
Engagement as interest / relevance	Learner-centered methodology advocates being sensitive to the habits, attitudes and needs of the students. This involves making learning episodes relevant and fostering independent learning and thinking. Many education reformers suggest that technology enhanced active learning is interesting and relevant to the internet generation. Another facet of relevance relates to the intrinsic motivation that stems from aligning learning activities with the professional goals of the students. Study Implications: The field test study used the construct of “interest” as one measure of engagement. The VPS allow learners choice and agency that fosters independent thinking. This study also measures the effect of a technology-enhanced instructional modality.
Engagement as flow	Researchers have defined the construct of “flow” and deemed it a valid measurement construct for one aspect of engagement particularly appropriate to educational games. Study Implication: The field test study used the construct of “flow” as one measure of engagement.

Figure 8. *Literature review: Theories of constructivist learning.*

While many attributes of constructivism support the design of this intervention, situated learning was selected as the primary grounding sub-theory (Lave & Wenger, 1991).

Innovation implementation theory provided key strategies for moving the VPS exercises from design to implementation. These theories recommend the development of a community of practice (steering committee), collaborative leadership, a participatory disposition, iterative design process, and sensitivity toward the curricular eco-system (Fullan, 2011; Senge, 1990, Wenger, 1998). Key literature findings for innovation implementation theories are summarized in Figure 10.

Concept	**Literature Findings**
Community of Practice (CoP) Theory	A CoP or steering committee may be employed to facilitate the innovation. This innovation team is also referred to in the literature as: high performing team, affinity group, or value-driven network. <u>Implications for this Study</u> The TEAL team is the CoP for this innovation. This team met weekly, established a culture of contribution and affinity, and arrived at consensus regarding values and processes. This strategy led to the continued support of a growing collaborative of faculty. Team members created the VPS. The CoP served as an advisory board to the research study and the development of data collection tools.
Fullan's principles for innovation implementation	Fullan's (2011) principles outline specific strategies with regard to communication about the innovation project. <u>Implications for this Study</u> This study infuses some of the elements of participatory research. It resulted in an ecological view of the research within the organization, and advocated the use use a respectful, conciliatory, communication-rich approach.
Innovation Integration Theory	Design-based researchers and organization experts such as Senge (1990) emphasize systems thinking. They suggest that the educational innovator must strive to harmoniously and collaboratively gain the acceptance of the innovation within the institution. <u>Implications for this Study</u> This study follows the iterative design principles of design based research. Each design decision should be documented with an evidence base from trying the lesson in the classroom. This study is responsive to the instructional and curricular cultures of the sponsoring school. Completing this study required gaining approvals from a wide range of stakeholders, testing the innovation iteratively, and disseminating those findings.

Figure 10. Literature review: Innovation implementation theory.

Chapter 3 will build on the literature review, providing an overview of the innovation and discussing the beta trial and field test results.

Chapter 3 – The Innovation and First Implementation

Landscape Analysis of Game and Simulation Platforms

Earlier I described the process of forming a community of practice for developing technology-enhanced learning activities and games. Following a DBR approach to game and virtual simulation development, after forming a mission and goals, the first step was to conduct a landscape analysis (Edelson, 2002). In reviewing published medical education games and simulations over a two year period, the TEAL team explored many genres including quiz show games, VPS, video games, and mobile apps. Over the course of academic year 2010-2011, the TEAL team experimented with the four game platforms as shown in Figure 11.

Platform	Use	Duration	Year	Type
Audience Response TurningTechnologies (2010).	**Group Practice**	**5 min.**	**1-2**	**Pause Activities** "Active learning episodes"
Quiz Show *Quiz Show, Spin Off and Billionaire* c3 SoftWorks (2010).	**Group or independent Practice**	**20 min.**	**1-2**	**Case Questions** "Engaging"
Mobile Game Application *Prognosis-ATSU* Medical Joyworks (2010).	**Independent Practice**	**5 min.**	**2-4**	**Linear Patient Case** "Just in time practice"
Virtual Patient Simulation *Decision Sim* Decision Simulation (2011).	**Group or independent Practice**	**25 min.**	**1-4**	**Branching Patient Case** "Training scenarios"

Figure 11. Simulation and game implemented by the TEAL team.

Experimentation involved progressive mini design based research cycles. For example, experience in learning to write quiz show games and mobile application games was a precursory in learning to design an ideal, complex, case-based serious game (a game used for professional training) such as virtual patient simulations. While the game platforms described in Figure 11 may be placed on a continuum from simple to complex, they continued to coexist in the curriculum as requested by course directors.

The TEAL team faculty first experimented with quiz show games. Interviews with three TEAL team faculty indicated that they felt the c3 SoftWorks Bravo™ quiz show games were engaging, but most useful for review of facts and knowledge (McCoy, 2011b). When a game is designed in the quiz show "Jeopardy" format, students may select any question in any order. This random design is not consonant with a real life unfolding patient case scenario. Despite the fact that these quiz show games are engaging, they are limited in terms of providing practice with a patient case as it logically unfolds and progresses. Furthermore, quiz show games are not recursive, a condition in which arriving at the solution to the final problem (such as diagnosis) depends on a chain of earlier decisions. A recursive, decision tree format is more consistent with decision making in medicine. Therefore, the TEAL team preferred a virtual simulation platform with branching decision pathways.

Inductive VPS

The TEAL team sampled several commercially available VPS, but decided not to purchase any completed cases off the shelf due to their hypothetico-deductive approach to clinical reasoning. Quite a few existing VPS are written in other languages besides English (University of Pittsburgh, 2011). Others such as eCLIPPS™ (University of Pittsburgh, 2011) appear to present the case beginning with a disease, not a clinical presentation. Sometimes these cases immediately ask the player for the differential diagnosis as is common with VPS via UptoDate™. Furthermore, for the TEAL team faculty, the prospect of revising existing cases to reflect a scheme inductive approach could take just as much time as developing new ones. These faculty translate paper cases written with a hypothetico-deductive approach to the scheme-inductive approach on a daily basis. The TEAL team hoped that VPS would eventually reduce costs and personnel by reducing the tutor’s case preparation load.

The TEAL team faculty felt that the new VPS cases should match the topics current in the curriculum at their own medical school. To date, VPS reflecting the clinical presentation scheme inductive approach simply do not yet exist. Proprietary, pediatric web-based course units exist in Australia (Pinnock, 2012). As of November 2012, literature searches in Pub Med and ERIC under keyword phrases “Inductive virtual patient simulation” “Induction VP Simulation,” and “Inductive Reasoning and computer games” did not render any results.

The Need for VPS Research with a Clinical Reasoning Focus

There also appears to be a gap in the literature for studies that investigate the utility of VPS for teaching inductive or forward clinical reasoning skills. In their summative literature review regarding VPS, Cook and Triola (2009) report only five studies on virtual patients and clinical reasoning. A close examination of these five studies did not reflect a focus specifically on designing a VPS using induction or clinical presentation schemes (Farnsworth, 1997; Janda et al., 2004; Kamin, O'Sullivan, Deterding, & Younger, 2003; Kumta, Tsang, Hung, & Cheng, 2003; Lowdermilk & Fishel, 1991)***.*** Authors Cook and Triola indicated that more research should be conducted regarding VPS for clinical reasoning, and challenge medical educators to elucidate the relative advantages of VPS as compared to mannequin and standardized patient (patient actor) simulations. Although very recently Bateman, Allen, Kidd, Parsons and Davies (2012) investigated Decision Simulation VPS and clinical reasoning, their study compared efficacy of branching designs and the structure of feedback rather than scheme-inductive reasoning. In summary, the development of VPS case simulations using inductive, evidence-based reasoning will advance the discourse in this field of study and support a fresh perspective on best practices in clinical reasoning.

The Innovation: A Scheme-Inductive VPS

For the reasons mentioned previously, the TEAL team decided to develop new VPS using the scheme-inductive reasoning approach. In 2011, the school purchased student and faculty accounts in Decision Simulation^{TM} (DS). The cost per student account per year was $32. Students log on to the Decision Simulation website and access the patient cases. The case player presents a case in an interactive learning module (see Figure 12). Gradually, the TEAL team faculty learned to author cases by way of technical assistance and by reading manuals. Other advantages of VPS are discussed in Appendix I.

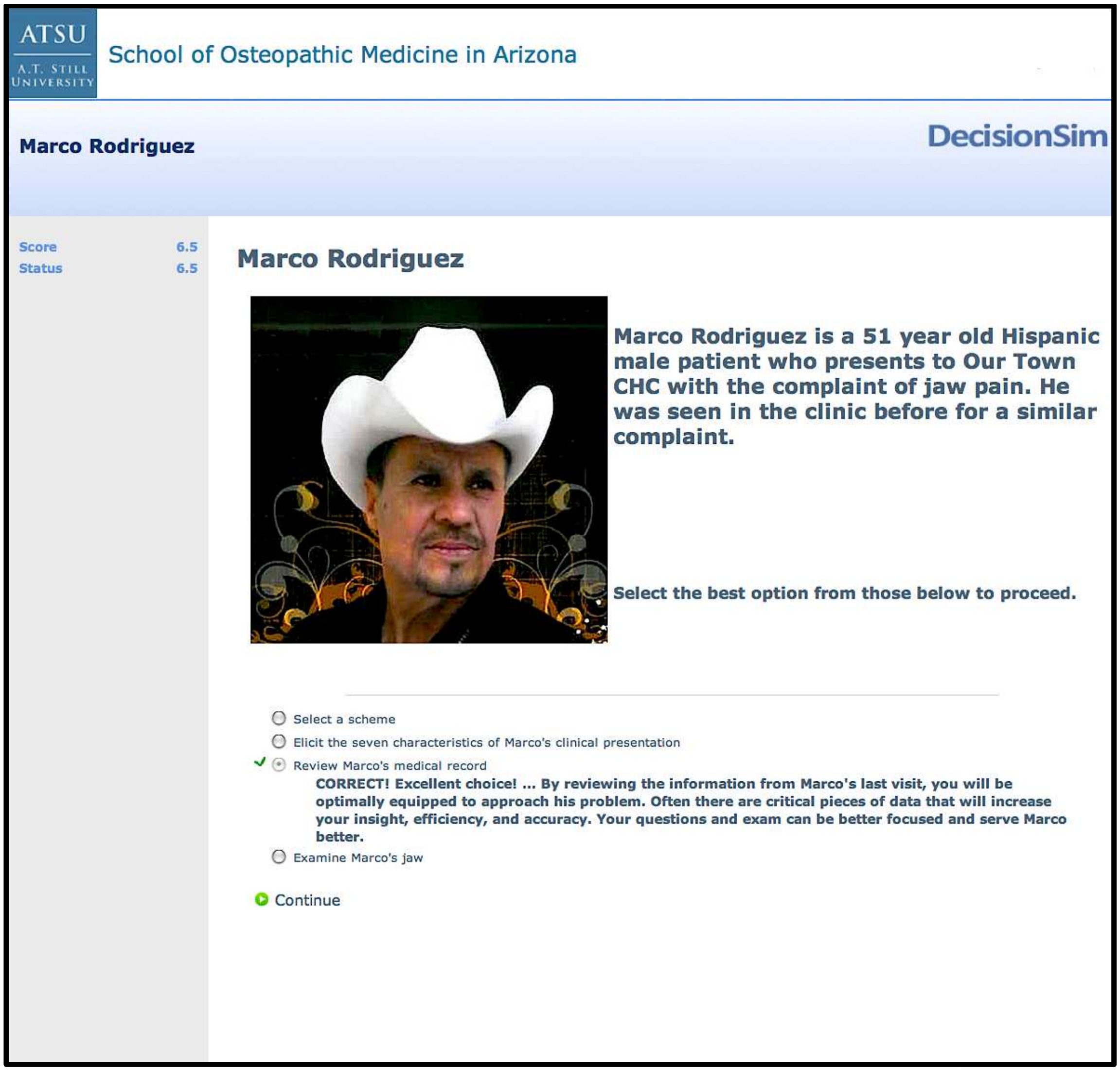


Figure 12. A sample VPS case, with cost, score, and step meters. Reprinted with permission (SOMA TEAL Team, 2013).

Features of the New VPS Series

Gamification elements. The new VPS modules were outfitted with game-like features, often described as gamification elements (Deterding and Dixon, 2011). These included meters for score and status, dramatic story line, rewards for high scores such as humorous "reward videos", and auto-play sound and video. Each VPS included a standard 100- point system. Some of the VPS included a meter for 'status', meaning the health status of the patient. Others included a meter for "cost of care." Over time, VPS authors learned to connect characters from case to case, and add additional gamification elements such as reward videos upon achieving a target score, and a community medicine thematic backdrop. One VPS design involved three levels of patient outcome: the patient recovers fully, the patient requires surgery reducing quality of life, or the patient dies.

Primary care clinical presentations. By February of 2014, the library of new VPS had grown to 22 cases addressing the following clinical presentations: seizure, eye redness, chest pain, constipation, febrile infant, runny nose, sore throat, headache, trouble breathing, diarrhea, dizziness, and oral complaints, and palpitations.

Branching design. Figure 13 illustrates a partial case map for one simulation.

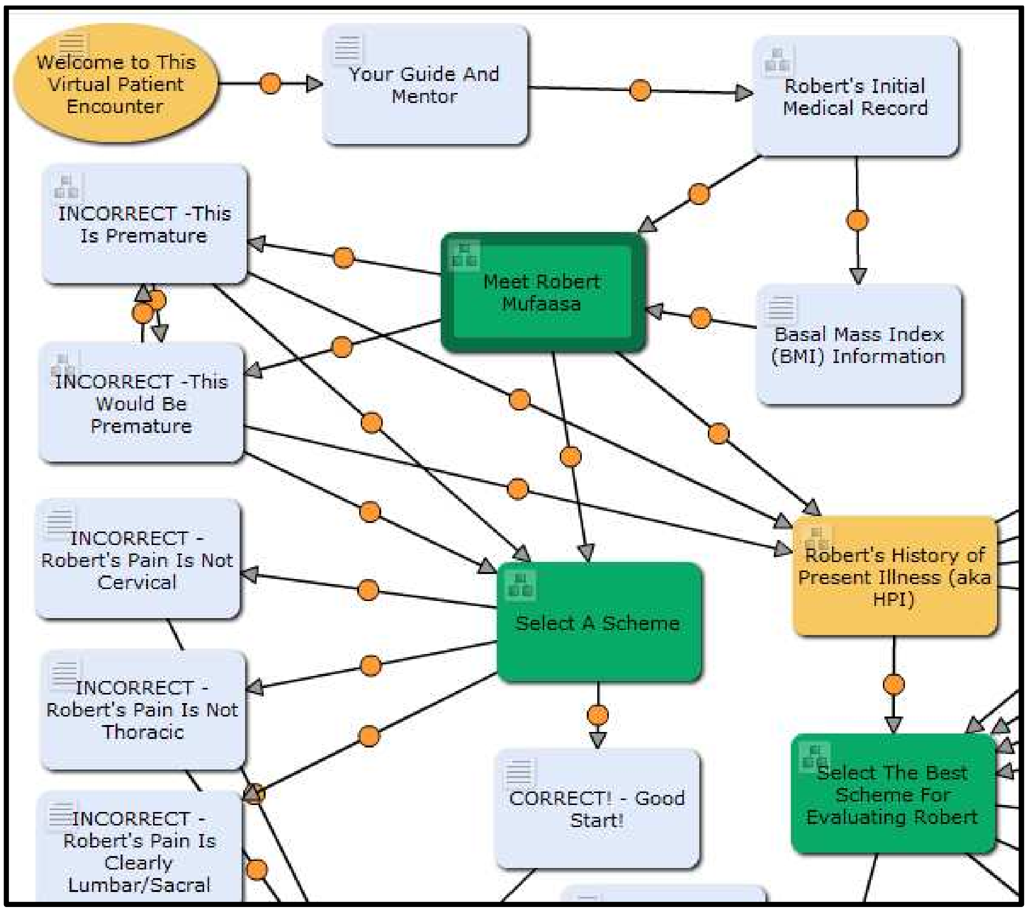


Figure 13. Partial case map, branching design. Reprinted with permission. (SOMA, TEAL Team, 2013.)

Each node or box in the map represents a page in the session. According to Ellaway et al. (2008), virtual patient cases may include linear designs (strictly guiding the student down a specific pathway), or branching designs “a tree-like structure of available pathways allow students to select the best option at each stage of the case” (p. 171). The VPS under study employ a branching design. Figure 13 depicts a branching case session, with recursive decision paths. For example, at the node (box) beginning with the text ‘*Meet Robert Mufaasa’* the student can select from three choices: select a scheme, take a history, or order a lab test (which would be premature). The student makes a decision that will divert them down a branch of the case story. The TEAL team selected the branching design because it supports clinical decision-type choice “challenge” exercises, allowing student agency and self-direction through the clinical vignette.

Multi-media format. The DS format provides decision dilemmas to students in a web-based ‘case player’, a format which affords the ability for video, sound, and links to be embedded. This instructional modality is suitable for a new generation of students who grew up in a video game era (Johnson, 2006).

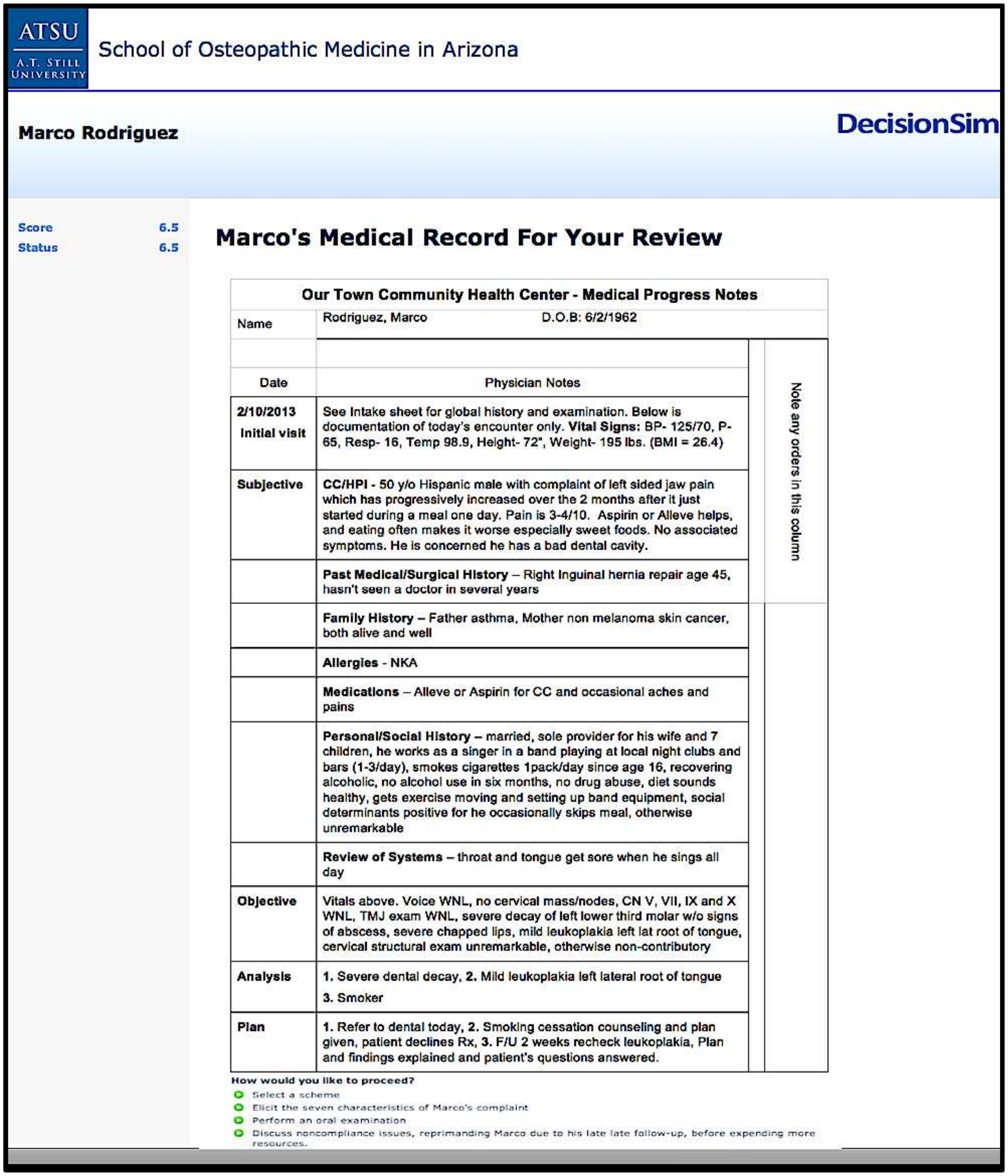
Competency alignment. Since VPS provide results reports and track student decisions, the TEAL team realized that VPS should target specific competencies and track student skills.. Following the competency design philosophy described by Shute, the TEAL team sought to align the VPS with specific competencies. In 2012, the TEAL team identified six main competency areas using a modified Delphi process (Custer, Scarcella, & Stewart, 1999). These competencies would be used to delimit and target skills sets with the first series of 25-minute Decision Simulations for first-year students. The competencies were then aligned to the American Association of Colleges of Osteopathic Medicine (AACOM) (2012) competency domains such as patient care, medical knowledge, communication, and professionalism. Figure 15 outlines the competencies and descriptors. Correlating lesson components to specific competencies provides the medical school with evidence of alignment with national competencies.

AACOM Competency	The student will be able to..	by...
Patient Care 3.1.j. Perform the patient encounter as appropriate for the situation.	1. Define a clinical presentation.	Choosing an appropriate a scheme
Patient Care 3.1.b Take an accurate history by communicating effectively—verbally and non-verbally—with patients and families in a variety of simulated and/or clinical settings.	2. Gather evidence through a patient history.	Selecting appropriate history investigations.
Patient Care 3.1.d Apply appropriate knowledge to the performance of the physical examination.	3. Use evidence from physical examinations to make clinical decisions.	-Selecting appropriate physical examinations. -Prioritizing PE investigations as either essential vs. non- essential.
Patient Care 3.2.b Generate and test multiple hypotheses during the course of the medical interview and physical examination.	4. Apply pertinent evidence at each decision point in the patient case, by sorting the data through inductive investigation.	Synthesizing evidence to select or prioritize lab and imaging investigations.
Medical Knowledge 2.3.a. Use scientific concepts to evaluate, diagnose, and manage clinical patient presentations and population health.	5. Apply medical knowledge to clinical investigations.	Defining appropriate lab tests/imaging/basic science relevant to the case.
Communication 4.4.a Collaborate with other health care professionals in the care of the patient demonstrating effective personal skills and interpersonal dynamics.	6. Exhibit effective interpersonal dynamics	Working in a student team to make clinical decisions (for team-based simulations).

Figure 14. VPS competency areas aligned to national standards. Reprinted with permission (SOMA TEAL Team, 2013).

Scaffolding mechanisms. The VPS interventions described in this study are outfitted with three main scaffolding affordances: diagrams, written feedback, and peer-collaboration prompts.

Flow Charts. The first type of scaffold within the VPS is a scheme flow chart. Scheme flow charts provide step-wise practice in solving cases. Expert physicians may not require flow charts, but in year one, they provide a ‘big picture’ map, and ,in the words of Barron (2002), a joint problem-solving space at solution-critical moments. The simulation leads students down the branching pathway of choices, providing structured inquiry, providing mechanics that assist students in ruling out wrong pathways. This provides structure and logic, scaffolding students toward prioritizing the patient evidence. This process establishes boundaries around the great quantities of unbounded data (possibilities). Rimoldi and Raimondo (1998) write, “Solving a problem requires, among other things, the reduction of the uncertainty inherent to it by requesting and organizing the information that subjects consider will help to reach a solution and thus reduce entropy" (p. 217). Other VPS graphic organizers include electronic health records.


ATSU A.T. STILL UNIVERSITY School of Osteopathic Medicine in Arizona

Marco Rodriguez

DecisionSim

Score 6.5
Status 6.5

Marco's Medical Record For Your Review

Our Town Community Health Center - Medical Progress Notes		
Name	Rodriguez, Marco D.O.B: 6/2/1962	
Date	Physician Notes	Note any orders in this column
2/10/2013 Initial visit	See Intake sheet for global history and examination. Below is documentation of today's encounter only. **Vital Signs:** BP- 125/70, P-65, Resp- 16, Temp 98.9, Height- 72", Weight- 195 lbs. (BMI = 26.4)	
Subjective	**CC/HPI -** 50 y/o Hispanic male with complaint of left sided jaw pain which has progressively increased over the 2 months after it just started during a meal one day. Pain is 3-4/10. Aspirin or Alleve helps, and eating often makes it worse especially sweet foods. No associated symptoms. He is concerned he has a bad dental cavity.	
	Past Medical/Surgical History – Right Inguinal hernia repair age 45, hasn't seen a doctor in several years	
	Family History – Father asthma, Mother non melanoma skin cancer, both alive and well	
	Allergies - NKA	
	Medications – Alleve or Aspirin for CC and occasional aches and pains	
	Personal/Social History – married, sole provider for his wife and 7 children, he works as a singer in a band playing at local night clubs and bars (1-3/day), smokes cigarettes 1pack/day since age 16, recovering alcoholic, no alcohol use in six months, no drug abuse, diet sounds healthy, gets exercise moving and setting up band equipment, social determinants positive for he occasionally skips meal, otherwise unremarkable	
	Review of Systems – throat and tongue get sore when he sings all day	
Objective	Vitals above. Voice WNL, no cervical mass/nodes, CN V, VII, IX and X WNL, TMJ exam WNL, severe decay of left lower third molar w/o signs of abscess, severe chapped lips, mild leukoplakia left lat root of tongue, cervical structural exam unremarkable, otherwise non-contributory	
Analysis	**1.** Severe dental decay, **2.** Mild leukoplakia left lateral root of tongue **3.** Smoker	
Plan	**1.** Refer to dental today, **2.** Smoking cessation counseling and plan given, patient declines Rx, **3.** F/U 2 weeks recheck leukoplakia, Plan and findings explained and patient's questions answered.	

How would you like to proceed?

- Select a scheme
- Elicit the seven characteristics of Marco's complaint
- Perform an oral examination
- Discuss noncompliance issues, reprimanding Marco due to his late late follow-up, before expending more resources.

Figure 15. A patient health record within a virtual patient case. Reprinted with permission (SOMA TEAL Team, 2013.) OurTown CHC™ refers to the name of a fictional community health center.

While students were allowed to take notes during the case, due to time constraints, students requested an electronic health record as a constant reference tool. During the case, students may refer back to the patient's health record, which gradually builds during the case.

Written feedback. During VPS practice sessions, student teams of 3 study through the lesson and get orientated to the case. Triad teams must decide together on answer choices. When the team selects a choice in the virtual case, the VPS module provides prefabricated, written, immediate feedback about the decision. This is the voice of the instructor; it is a feature helpful for teaching students with a wide range of abilities who may be reluctant to raise their hands during traditional instruction when they are confused.

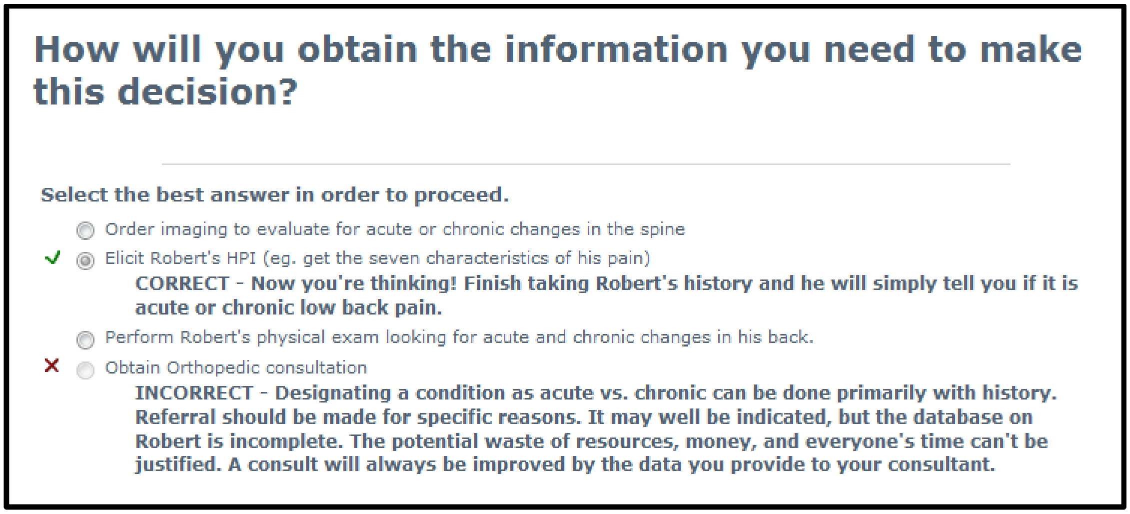


Figure 16. VPS written feedback. Reprinted with permission. (SOMA TEAL Team, 2013.)

Master clinician small group tutors lead debriefs with students after the VPS. Debriefs allow the opportunity to clarify concepts, reinforce weak areas, and correct misconceptions. Once students have completed a VPS case, they can more efficiently use time with tutors to explore nuanced issues, clinical pearls, or higher order questions (as defined by Bloom's Taxonomy, 1984).

The VPS feedback mechanism also allows for a gold standard of explanation. During the process of implementation, the cases are peer reviewed, and the medical content verified via multiple sources of medical guidelines. During tutor preparation workshops just prior to the instructional session, authors, tutors, and course directors discuss case specifics. These collaborative aspects of VPS development allow faculty of medicine to align their perspectives on the various cases (Bateman, Allen, Kidd, Parsons, & Davies, 2012). Because students can self-navigate through the sessions, the team felt that these VPS might be very useful for distance education as well as peer-learning situations. The cases can be distributed online to remote groups of students through a website.

Peer collaboration. When students are working in teams on a given case, virtual simulations provide a non-threatening space for student inquiry with peers. The environment is safe because the simulations are formative and low stakes; they are purely for deliberate practice. Students are playing through the simulation in explore mode. As first-year students, they are not playing to "win" (in assessment mode), and they can discuss options together to scaffold learning from peer to peer. While required to attend, students are not graded on their scores, and students may explore the reasons why certain choices are not correct.

Beta Trials

Through iterative cycles of implementation, VPS authors refined the lesson architecture, refined a scoring system, and improved the usability (functional aspects) of the cases. Initial beta trials were conducted during the 2012 NMsk course (described in Appendix H). During each VPS session, teams of medical students assumed the role of the physician and directed the investigation of the patient case. The goal of integrating these virtual patient cases within the existing curriculum was to enrich and enervate weekly small group patient case practice with episodes of interpretive discussion, choice/feedback, and collaborative inquiry. After a round of beta trials, it appeared that students and faculty seemed interested in this mode of instruction. Feedback and insights collected were used to improve the VPS.

During this same phase, I conducted observations of standard patient (SP) simulations and mannequin simulations with the same cohort of students. In comparing VPS with standard patient simulations and mannequin simulations, I noted that VPS provide the following advantages not found in two other types of simulations: 1) immediate private feedback to each student, 2) interactive, branching decision pathway practice, 3) practice prioritizing specific evidence, 4) group or individual play, 5) feasibility for distance learning, 6) the need for fewer clinician tutors, and 7) student score reports.

Implementation I: Field Test

Phases of Research

This study employed a sequential, mixed-method, design-based approach, inclusive of survey methods and a pre-post crossover performance measure. The design is considered sequential since it reports two, subsequent phases of implementation (1 and 2) (Fig.17). Using a mixed methods approach, this study integrated both qualitative and quantitative measures (Creswell, 2009).

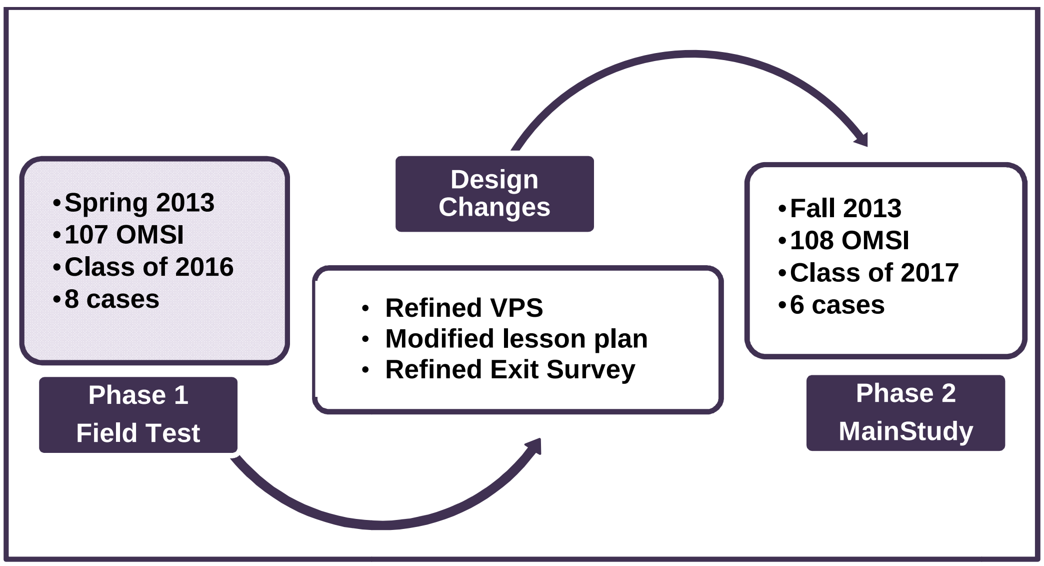


Figure 17. Research design in two phases.

Following design-based methodology (Barab & Squire, 2004), the virtual simulation was improved in between phase 1 and 2, based on the field test results.

Field Test Overview and Methods

Prior to the main study, a field test took place in May-June 2013 at ATSU-SOMA, during the Gastro-intestinal (G.I.) course. The results of this field test are reported in this section as implementation phase I. The methods, data collection instruments, and data analysis for this implementation are effectively the same as those described fully in the Methods section (Chapter 4), inclusive of institutional review board approvals. Participants were 107 first year students (class of 2016) and six of their clinical tutors. Data collection took place over four class sessions.

Sessions 1-3: VPS Practice. In each of the three sessions, students worked in teams of three to complete two 25-minute VPS cases during required class time. These cases addressed five primary care topics: stomach pain, weight gain, oral complaints, diarrhea, and constipation (2 cases). After working through each case, each student team submitted a Diagnostic Competency Task. I observed each of these sessions, and video recorded six small group classrooms. Two teams were randomly selected for video-recording in isolation, and these discussions subsequently transcribed.

Session 4: Exit Survey and Comparison Group Experiment. During the fourth session, in order to gather their impressions regarding VPS, students also completed an electronic Exit Survey. Finally, in an effort to test the effectiveness of VPS instruction compared to traditional methods, students participated in a comparison group experiment. First, the entire class of 107 was divided into two sub-cohorts (A and B). Both groups received the same two cases. One group received instruction via the traditional PPT method, and the other via VPS. This allowed a comparison of pre- and post-test learning gains among traditional (control) and virtual simulation (intervention) modes. In this section, I briefly synopsize the results and discussion for each of the main findings of this implementation by research question.

Field test research question 1: Clinical decision-making

Research question 1 asked: To what extent do VPS increase skills in clinical decision making?

Field Test Hypothesis 1a: Competency task. Hypothesis1a stated: Students will demonstrate competence by accurately completing a competency task. To test this hypothesis, after working through each case for 25 minutes in a team of three, each student triad team submitted a Diagnostic Competency task. Table 1 reports competency task results for these sessions.

Table 1

Diagnostic Competency Task Performance by Case Topic

Session	Case Topic	# of Student Teams	% Correct Diagnosis	Gamification Elements
1	Stomach Pain	30	100%	Reward video for scoring above 80%
2	Weight Gain	30	100%	
3	Oral Complaints	33	100%	Outcomes, multi-media
4	Diarrhea	31	97%	
5	Constipation - 1	30	90%	Community health clinic setting
6	Constipation - 2	30	97%	Longitudinal connected cases between two family members
	Mean		97.3%	

Discussion. Student team performance on competency tasks indicated that triads arrived at the correct ballpark diagnosis for 6/6 cases with a mean accuracy of 97.3%. From these results, Hypothesis1a, *Students will demonstrate competence by accurately completing a competency task*, was affirmed. VPS case number three 'Oral Complaints' featured gamification elements, inter-professional teamwork, and a contextual theme. This case was created through inter-professional collaboration between a physician and a dentist, set in a community health center, and featured a dramatic "outcomes" trope (format). Depending upon student decisions, the virtual patient: 1) recovered fully, 2) recovered with some adverse consequences, or 3) died. Thirty two student teams provided short answer responses reporting on the patient outcome. At least 70% of the student teams clearly reported an optimal outcome for their patient (optimal –full patient recovery). A sample student team response:

> Neoplasm is in the mouth. He didn't have enough money to take care of it so we referred him to community health center (CHC) social services who found a way to pay for the surgery. He got the surgery and made a full recovery.

The take away from this episode was this: while time consuming to review, it is very useful to collect student open responses to debrief questions after the case.

Field Test Hypothesis1b: Pre- and Post-Test. Hypothesis 1b stated: There is a difference in effectiveness between virtual patient simulations and traditional case practice for teaching students clinical reasoning skills, as measured by a difference in mean gain between pre-and post-tests. Just after participating in the Field Test Exit Survey on June 18 2013, 106 students (99%) participated in a comparison trial. Following methodology outlined in Chapter 4, a curriculum coordinator randomly assigned all 107 first year students into two sub-cohorts of students (A & B). One student was absent (see Figure 18).

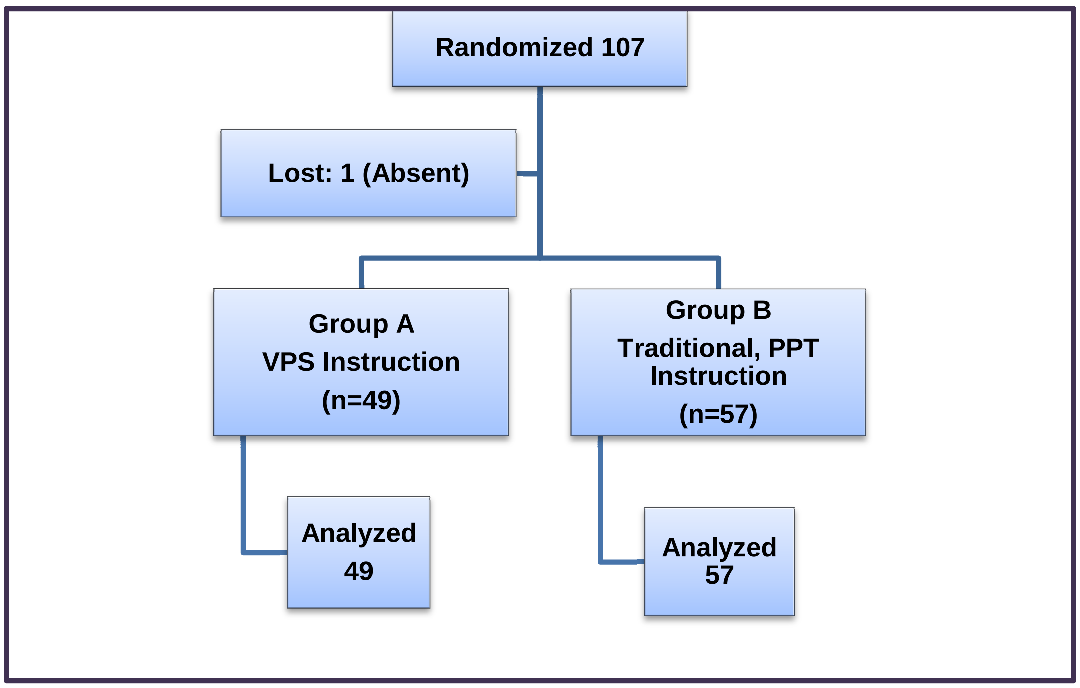


Figure 18. Flow diagram of student allocation.

There were more students in Group B because pods of 8-10 students were randomly allocated to two separate groups. Groups A and B met in separate locations concurrently. Group A (intervention) was distributed to five small group rooms, while Group B (control) met in the large group classroom. In both locations, students individually completed a 20-item multiple choice pre-test, followed by instruction with two half-hour cases, followed by a 20-item multiple choice post-test. Group A (n = 49) received the intervention instruction in triads using VPS, while the control Group B (n = 57) received case instruction via traditional PPT in large group. The instructor for this large group presentation was randomly selected from the pool of small group tutors. This instructor was a physician, a DO with five years of teaching experience and five years of clinical practice. The case vignettes for both the intervention and control sessions were derived from the same case PowerPoint.

During data analysis, a Box's Test of Equality of Covariance Matrices indicated that the pre-post correlation was equal across groups (2.73), p = .445. Cohort A (the intervention group) scored a mean learning gain of 12.55% between pre-test (68.47%, SD=1.32), and post-test (81.02%, SD=.98). Cohort B (the control group) scored a mean gain of 8.24% between pre-test (68.51%, SD = 1.79), and post-test 76.75%, SD= 1.37). A multivariate analysis (MANOVA) F (1,104) =3.06 revealed that the difference in mean change score (learning gain) was not significant, p =.06, η^2 .034. Since the power statistic .469 for the sub-groups was not sufficiently robust according to the minimum of .8 required (Park, 2010; Greene, 2000) a crossover was added to the comparison design in the second phase (main study). A crossover comparison trial design allows both comparison groups to study in both modalities of instruction, increasing the sample size per instructional modality and consequently improving the power (C. Bay, personal communication, February 16, 2014). A sample size of 100 participants allocated 1:1 will yield 80% power to detect an effect size F as small as 0.15 **(**η^2 =.02), assuming a moderate correlation among repeated measures (r = 0.50).

Discussion. These field test findings did not confirm Hypothesis 1b, 'There is a difference in effectiveness between virtual patient simulations and traditional case practice for teaching students clinical reasoning skills, as measured by a difference in (significant) mean gain between pre-and post-tests'. During this field test, there was inconclusive evidence to entirely confirm that VPS increase clinical reasoning significantly. The group that received the intervention (VPS) instruction made better gains than the control group, but the results narrowly missed being significant. However, these results did provide evidence that the study design was feasible. They pointed to the need for a formal re-test in the fall of 2013.

Field Test Research Question 2: Student Perceptions Regarding VPS.

Research Question 2 asked: What are year 1 student impressions of VPS instruction in terms of critical thinking skills, engagement (relevance and flow), and collaboration? On the final session of the field test, 105 first year students participated in an electronic survey during class hours. With a response rate of 95%, 102 respondents were 52% male and 48% female. They reported their ages as 22-25 (47.1%), 26-30 (40.2%), 31-35 (7.8%), 36-40 (3.9%), and 41+ (1%). The exit survey measured student impressions regarding the VPS in four factors: critical thinking, interest, flow, and collaboration. Likert labels *Strongly agree*, *agree, neutral, disagree, strongly disagree* were converted to an ordinal scale of 5-4-3-2-1. For all data reported, percentages for agree or strongly agree were aggregated.

Construct 1: Critical thinking. Approximately two-thirds (65.4%) of respondents strongly agreed or agreed that the VPS provided practice with schemes used in inductive reasoning. More than half indicated that these activities increased evidence sorting abilities (53%) or integrated theory with practice (52%). More than one-third (36%) felt the VPS helped with review for exams.

Construct 2: Interest and engagement. In order of high to low ratings, respondents reported that the VPS added variety to the learning environment (69.6%), and provided exposure to new experiences (62.4%). Just under half of respondents indicated that VPS increased interest in clinical practice (49%) or provided relevant feedback (45.1%).

Construct 3: Flow. Flow is a measure of the student's **"**absorption in task." This factor was designed with Likert items validated by Shiefele and Raabe (2011). Combining categories *strongly agree* and *agree,* nearly half of respondents highly rated 'enjoyed working on the tasks' (46.7%). Fewer were completely absorbed in the activities (28.7%), did not realize how time passed during the exercise (25%), or found the tasks to be quite exciting (23.8%).

Construct 4: Collaboration. Collapsing categories *strongly agree* and *agree* percentages for each statement , brainstorming with fellow students was helpful (77.4%), group discussion clarified concepts (72.5%), group decision making was useful (72.3%) and working in a small team of three students allowed better participation than working in groups of 10 (61.8%).

Discussion. Research Question 2 probed: What are year 1 student impressions of instruction in this modality of virtual patient simulation in terms of critical thinking skills, engagement (relevance and flow), and collaboration? Data collected from the electronic Exit Survey inform this question. Overall, students provided highest ratings in the category collaboration. Students also found this VPS modality most valuable for practice with schemes, engaging in new experiences, and for providing variety. Items related to clinical relevance and preparation for exams were more lowly rated. The evidence regarding whether students were "in the flow" is inconclusive. Judging from survey responses, students were generally neutral about whether they were in the flow of the lesson, but upon observation over three sessions during the field test, digital ethnography including 40 photographs indicated 85% of the students were engaged in terms of participation or concentration, and their tutors indicated via feedback forms that the students were engaged. Preliminary analysis of student discussions during VPS indicate that students were engaged in discussing aspects of the case but there were also periods of silence while students read screen text, confusion, and frustration at some points in the cases. From these results, I realized the importance of streamlining VPS content and providing clear guidelines for collaboration.

While the digital records (video and photographic) of these sessions provided ample positive indications of student participation and engagement, it was not possible to publish video footage or photographs without the student's express permission. Students were extremely tired the day this survey was administered just prior to a final exam of the entire school year. For this reason, I surmised (and it held true) that students would rate aspects of the VPS more highly during the second implementation phase, October-December 2013.

Field Test Research Question 3: Design Mechanisms of the VPS

Research question three inquired: Which mechanisms in the VPS allowed the students to effectively complete a competency task? According to Cobb et al. (2002), design studies are test beds for innovation. These studies should contribute 'humble' theories useful for explaining domain-specific learning processes—theories that must 'do real work' in informing the specifics of consequent design of instruction.

Method of data triangulation. Following petite generalization methodology (Barab & Squire 2004; Stake 1995), three data sources provided insight into the specific way the VPS mechanics supported rich discussions among student teams which scaffolded learning and resulted in successful completion of competency tasks: 1) transcribed student dialog, 2) screen captures of the VPS to illustrate what the students were discussing, and 3) photos of VPS session to illustrate student demeanor, also known as affect, during the sessions under study.

Transcribed student dialog. During each of three observation sessions, I randomly selected a small group room to observe remotely via video camera from the control room and used an observation protocol to note student behaviors for 1.5 hours each session. During this process I primarily observed the action in one small group room, but also scanned the master TV monitor screen showing action in all of the small group rooms. Two faculty members joined me in observing the first session and they member checked my findings. Following these sessions, I transcribed two 20-minute sessions of student dialog during the VPS case.

Themes which emerged from these transcriptions indicated that while these VPS involved too much reading impeding some discussion, the students often participated in collaborative discussion; they discussed patient evidence, the patient chart, imaging, scheme flow charts, and the point system.

Discussion. I was able to affirm *Petite Generalization 1*, generalizable only to this study's classroom context: The VPS afforded students opportunities to assemble evidence to make key decisions in the case. However, the transcriptions revealed the need for improvement of VPS format and scaffolding of instruction with regarding to sorting patient data. Also, students seemed interested in discussing questions with tutors. For this reason, for the next implementation, the design encouraged tutors to circulate to answer student questions during the VPS sessions. The new lesson plan included a 10-minute debrief with tutors post-simulation.

Each VPS was designed with a 100-point system, which, from animated comments during the sessions seemed to motivate students. Other comments indicated that students wished the point system would not inhibit their natural curiosity to click open all the decision options to read the feedback. The point system was in development at this stage of implementation. These findings were used to refine the point system.

Research question 4: Elements of the Intervention to Revise

Research question 4 considered: Which design elements of this intervention need to be revised for the next implementation? The results of this line of inquiry provided additional insight into specific aspects of the intervention that need revision prior to the next cycle of implementation.

Method of data triangulation. To answer this question, data were triangulated from the student exit survey open responses, tutor observation forms, transcriptions of student discussions, and photographs of the activity.

Exit survey open responses. In completing the Exit Survey, 105 students provided 61 open responses to “How may we improve these activities?” and 20 general comments. These responses were pooled, and individual phrases (statements) were open coded into 11 categories.

1. Independent study. Fifteen students wanted to be able to access the VPS at home or complete them at their own pace apart from other classmates.
2. Tutor facilitation. Thirteen students expressed that the tutor should circulate to answer questions during the 3-person interaction or the discussion would be more useful in a group of ten.
3. Case format. The students called for more consistency in how the cases unfolded. They requested less text. They indicated that the scoring system somewhat inhibited the intentional exploration of all options.
4. Case content. Some students requested surprise schemes instead of predictable schemes. Others wanted case content pared down to “just the essentials.” Their explorations did not always provide them with clarity when faced with decisions because they could not compare data on several screens at once. A few students raised issues regarding the best clinical practices.

5. Feedback. Students wanted very clear feedback on which lab and imaging tests they should and should not order.
6. Mechanics or usability. Students wanted to either check a patient chart or be able to track backwards in the session to prior screens. They suggested revealing all the answers once an option has been selected to review feedback on wrong options.
7. Teamwork. Four comments were positive regarding teamwork. One requested students to work in pairs, one mentioned that some students like a fast pace while others are more methodical.
8. Time or pace. Four students mentioned that some student teams were racing through the lesson. One student suggested placing time limits (though they had been set).
9. General approval. Three students expressed that the exercises were helpful, useful, or a good idea. One expressed thanks.
10. General disapproval. Four students expressed that they did not want to complete this type of VPS.
11. Proofreading. Students requested professors to avoid typos.

Tutor feedback. In general, the tutors provided positive feedback, but also pertinent, concrete suggestions about the case content. They also indicated that students could not finish the VPS in 20 minutes. They suggested streamlining the length of the VPS and reducing the amount of text.

Photographic images*.* Practice sessions ongoing in each small group room were video recorded. In reviewing these recordings, I randomly captured 40 photos from video in order to analyze them inductively to discover trends converging toward themes. When analyzed through the process of open coding (Corbin & Strauss, 2010), these photos provided additional insight into what was working and not working in the lesson plan and the classroom environment. For example, the photographs yielded information about student group formations, modifications for distance training, and the use of outside reference materials**.** In five instances out of 40, at least one student in the group was not sitting closely enough to easily read the laptop screen. For this reason, during the next preparation session, tutors were requested to ensure a better “v” cluster around the laptop.

Westberg and Jason (2004) indicate that laughter is an indication of collaboration. Some of the photos and video footage reveal students smiling, nodding, or laughing. The laughter was in response to humor in the storyline, or surprise in gaining or losing points. Students also expressed pleasure and pride at achieving a high point total and the ensuing reward videos. The reward videos were funny clips that appeared for teams who received a score higher than 80 points out of a total100. Winners were observed playing the videos loudly, perhaps as trophies. In one classroom, classmates exclaimed, “turn it down! We are trying to concentrate on a case!”

The photographic images also conveyed what appeared to be focus on task. For example, in 34 out of 40 photos, student triads expressed an aspect of flow called “state of concentration” (Admiraal, Huizenga, Akkerman & Dam, 2011; Schiefele & Raabe, 2011). In these photographs, students leaned in close to the laptop computer screen. Additionally, in one session, I observed two students collaborating peacefully and effectively by Skype™ video-conference with a remote third team member. In a few of the sessions, I observed students pausing during the session to check other sources of information such as prior lecture PowerPoints, flash cards, and in one stance, a cell phone. In the medical school environment, a cell phone is often used to research a topic.

Discussion. This phase of implementation revealed valuable insights into the value and utility of VPS. This field test changed my perspective in four key ways. First, I realized the value in establishing and ratifying firm case-writing guidelines. Second, I was impressed by the outstanding cooperation and attitude received from the clinical tutors. While asked to take a ‘guide on the side’ role during this study, the tutors not only cooperated, but provided supportive comments and worked hard to ensure fidelity to lesson plan. No wonder the students hold these veteran primary care physicians in such high regard. Reviewing some student comments on the exit survey, students were reluctant to cede even 20 minutes of case practice time away from them. The third point was regarding collaboration. Although some students expressed the desire to work in a team of 10 with a tutor, the tutors were supportive of a smaller group of students working out issues in a peer-format**.** After compiling data, some ideas for implementation design changes surfaced. Figure 19 provides a summary of all the design changes that were planned.

Theme	**Issue**	**Design Solution**
Collaboration	From exit survey comments, it appears that students need reinforcement regarding the need for peer collaborative activities.	Provided students with guidelines for collaboration and consider adding a competency task.
Tutor's Role	Faculty prefer to circulate during VPS to answer questions.	Encouraged the tutors to circulate during the lesson to answer questions and provide a tutor-led 10 minute debrief after the lesson.
Patient Health Record	Students request ability to view prior pages of the case, and access the patient health record.	Added more VPS screens with patient health records. Began a two-year process of integrating writable electronic health records into VPS lessons.
Pace	Some of the students played through the cases quickly and others more slowly.	Emphasized the time limit (20 minutes), and appended a tutor-led 10 minute debrief to add structure.
Play vs. Team Play	15 students express interest in completing the VPS alone instead of in a group.	Emphasized to students that the VPS were available for single player practice online after each case.
Case Format	There was too much screen text, and variance among case formats.	Ensured that new VPS cases underwent peer review and proofing process. Refined case stylesheet and guidelines.
Student Groupings	In certain formations, at least one student was not easily able to see the screen.	Ensured that tutors received instruction regarding how to structure the triad formations.

Figure 19. Design changes implemented after running the field test.

In conclusion, field test data indicated that aspects of these VPS were somewhat challenging for first year students–perhaps due to the inductive nature of co-constructing knowledge. Nonetheless, clinical reasoning and collaboration were indeed taking place. For the next phase, additional items were added to the Exit Survey to further unpack the themes of clinical reasoning and collaboration.

Chapter 4 - Methods

Approach

Study Goals

The goal of this study was to investigate the utility of virtual patient simulations (VPS) for increasing medical student clinical reasoning skills, collaboration, and engagement. This mixed-methods, sequential, design based research study explored the effects of a medical education virtual patient simulation innovation. Qualitative and quantitative data were used to triangulate findings to improve the overall strength of the findings (Creswell, 2009). Research questions were refined slightly for the second implementation.

Research Questions, Second Implementation (Main Study)

Research question 1 inquired "For undergraduate medical students, year 1, to what extent does deliberate practice with virtual patient simulation improve skills in clinical decision-making?" To answer this question, I tested four hypotheses (A-D) (Fig.20). These hypotheses relate to Diagnosis Competency Task results, Pre-and Post-test results, and student perception of the value of the VPS for clinical reasoning (Exit Survey).

Research question 2 investigated "Which VPS mechanisms allowed the students to effectively make clinical decisions?" To answer this question, screen captures from the lesson design were juxtaposed with samples of transcribed student dialog during VPS sessions. These data sources illustrated petite generalizations such as "students engaged in rich conversations around a specific decision."

Research questions 3 and 4 inquired "In which ways do VPS foster peer collaboration /engagement?" To answer these questions, quantitative student Likert ratings regarding collaboration during VPS sessions were triangulated with data from session photographs, transcribed student dialog, and tutor feedback. These data sources provided '360 degree' evidence to evaluate whether the VPS were engaging and provided a collaborative learning space for students.

Research question 5 investigated, "Which design elements of this intervention need to be revised for the next implementation?” Data sources for answering this question included researcher observations, student open-answer comments on the Exit Survey, and tutor feedback. Figure 20 provides the research questions, data collection instruments, methods of data triangulation.

Research Question	Data Sources	Method of Data Triangulation
1. For undergraduate medical students, year 1, to what extent does deliberate practice with virtual patient simulation improve skills in clinical decision-making?	• Competency tasks* • Exit survey Likert ratings • Pre- and post-tests * As measured by a team mean of >80% on the competency task. **As measured by a significant difference in mean gain between pre-and post-tests.	Quantitative results from three data sources were used to test each of the following hypotheses. A chart tallying the results of each hypothesis was used to answer research question 1 (See. Ch. 6). A. Student teams will demonstrate competency in clinical decision-making as measured by accurately completing 4 diagnosis performance tasks. B. Students agree that VPS are valuable for practicing clinical decision making. C. VPS are effective for improving clinical decision making.** D. VPS are more effective than traditional instruction with PPT’s for improving clinical decision making skills.* *
2. Which VPS mechanisms allowed the students to effectively make clinical decisions?	• Simulation screen captures • Transcribed session dialog	Qualitative data from two sources were axial coded during the analysis stage and triangulated to affirm assertions. Graphics juxtaposing screen captures with student dialog and diagrams illustrating the central phenomenon were used to answer research question 2. (See. Ch. 6).
3. In which ways do VPS foster peer collaboration?	• Exit survey Likert ratings • Tutor feedback • Session photographs • Transcribed student dialog	Qualitative data from four sources were open and axial-coded during the analysis stage and triangulated to affirm assertions. Main themes identified were mapped to the construct of collaboration. (See. Ch. 6).
4. In which ways do VPS foster engagement?	• Exit survey Likert ratings • Tutor feedback • Session photographs • Transcribed student dialog	Qualitative data from four sources were open coded during the analysis stage and triangulated to affirm assertions. Main themes identified within the qualitative data were mapped to the construct of engagement. (See. Ch. 6).
5. Which design elements of this intervention need to be revised for the next implementation?	• Exit survey open comments • Researcher observations • Tutor feedback	Qualitative data from three sources of data were open coded during the analysis stage and triangulated to affirm assertions. Design issues to resolve were displayed in a chart. (See. Ch. 6).

Figure 20. Research questions and methods of data triangulation.

Variables

In this study, independent variables were mode of instruction and order of mode of instruction. The dependent variables were as follows:

- Clinical decision-making skills
- Peer collaboration
- Engagement

The first variable, clinical decision-making, is defined as the ability to make clinical decisions by reasoning inductively toward a ballpark diagnosis, integrating medical theory with clinical practice guidelines, gathering evidence during physical exams, prioritizing lab and imaging investigations, and selecting the sequence of the patient encounter. Improvement in clinical decision making is defined as the difference between pre- and post-test scores after instructional intervention and accurate performance on the Diagnosis Competency Task.

The second variable, collaboration, is defined as peer brainstorming, using team discussion to clarify concepts, group decision making, participating in a peer team of three, communicating respectfully, encouraging peers to express their opinions, and putting in effort.

For the purpose of this study, engagement was operationalized as relevance, interest, and flow. According to Bilde, Vanteenkiste, and Lens (2011), making learning relevant motivates students (2011). Following the research of Schiefele and Raabe (2011), engagement may be measured by the participant’s self-reported degree of flow (absorption in the activity) and concentration on task.

Control variables included tutor pre-preparation for their specific role during the intervention, student triad groupings, tutor blindness to the pre-and post-test items, blindness of students to the specific intervention module cases prior to practice days, and the specific timing and sequence of lessons and assessments. One potential limitation was that during the controlled trial, the content of the cases consisted more of “rote pattern matching of palpitations heart rhythm strips” as opposed to reasoning through a patient case. This constraint was unavoidable due to the time frame of the study.

Setting

Following a design-based research approach, this study included two cycles of implementation. Both took place at SOMA, an undergraduate medical school located in the southwest United States which supports approximately 420 students and 65 faculty. The first implementation was a field test that took place May 25, 2013 through June 3, 2013. The second implementation and main study took place from October 7, 2013 through December 18, 2013. This intervention took place in small group classrooms at the main campus. Data collection occurred during the Neuro-Musculoskeletal (NMsk) and Cardio-Pulmonary courses, as part of weekly small group sessions.

Both implementations were exempted by the study site's Institutional Review Board (IRB) and the Arizona State University IRB. The study site IRB advised that on the first day of data collection, researchers should provide participants with a document explaining the study. The participants were not required to sign this explanation nor a full consent, as this study was exempted and conducted as part of normal instructional activities for the benefit of quality assurance of instruction. The *Study Explanation* (see Appendix C) was distributed in writing to students at the beginning of the initial session, and read aloud to the students by their tutors.

Participants

For the second implementation, the entire class of 2017 OMSI (108 students) participated in the study as part of normal classroom activities. Student participants were 53% male, 47% female, 49% White, 37% Asian, 6% Hispanic, 1% Native American/Alaskan Native, 1% Black, 2% Pacific Islander, and 5% Unknown. They ranged in age from approximately 20-40. Six faculty small group tutors also participated in this study as part of normal teaching duties. Tutors were DO and MD physicians in the disciplines of family medicine, internal medicine, neurology, and pediatrics with 5-40 years of primary care practice and 1-15 years of experience leading small groups.

Measures

This study included seven measures: 1) Team Diagnostic Competency Tasks, 2) Pre-post, multiple choice question (MCQ) tests, 3) Transcriptions of student discussions during VPS sessions and traditional case practice, 4) VPS experience Exit Survey, 5) Tutor Feedback Form (submitted each session), 6) Researcher Session Observation Form, and 7) Session photos.

Measure 1: Diagnosis competency task. Hypothesis 1A states "Student teams will demonstrate competency in clinical decision-making by accurately completing a diagnosis performance task." To test this hypothesis, I used a Diagnosis Competency Task (see Figure 21).

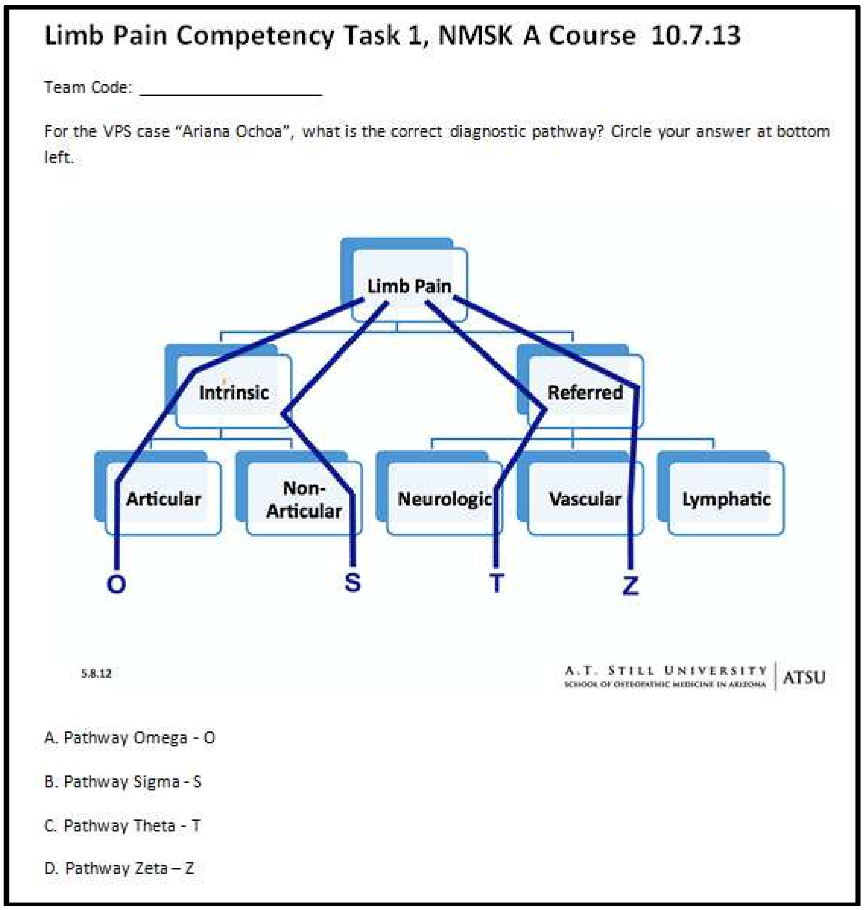


Figure 21. Sample diagnostic competency task. (SOMA TEAL Team, 2013)

As described earlier, the VPS provided students with guided practice in scheme induction. The results from the Diagnosis Task exercise were used to measure whether students were able to make decisions during the simulations, ultimately arriving at an accurate ballpark diagnosis. For the purpose of this study, ballpark diagnosis is defined as a general diagnosis, as outlined on the final tier of the scheme depicted. Prior to completing the VPS exercise and competency task, the students were provided with instructions (see Appendix M). Student teams of 3 to 4 navigated through a 20-minute VPS session. At the end of the VPS exercise, the student teams received the Diagnostic Competency Task on a paper document. Students completed the task as a team without the help of the tutor, and submitted it at the end of the lesson.

Diagnosis competency task development and validation. Prior to the study, there was no formative assessment during case practice, and felt that adding a formative exercise would improve case practice. To design the Diagnosis Competency Task, structured interviews were conducted with four key faculty members expert in CP method instruction. Faculty were shown an item such as the one in Figure 10, and requested to share their views on how best to design the Diagnostic Competency Task. All faculty interviewed reviewed the structure of this item and had no objection.

Next, VPS case authors drafted the Diagnostic Competency Tasks for the 2013 field test. The competency tasks were completed by peer teams after 20 minutes of VPS case practice and did not count toward the student grade. During the field test, these tasks worked well; student teams completed the exercises per lesson design. However, in order to add an opportunity for students to receive tutor feedback on their performance in the subsequent implementation (the main study), I added a ten-minute tutor-led discussion called a case *debrief*. The objective of the debrief session was to provide the students an opportunity to discuss the correct ballpark diagnosis or remaining muddy conceptual areas.

Measure 2: Pre- and post-tests. Hypothesis 1B states “VPS are more effective than traditional PPT case practice for teaching students clinical reasoning skills, as measured by a difference in mean gain between pre-and post-tests.” To test this hypothesis, a set of multiple choice pre- and post-tests was used to compare mean learning gain between pre- and post-tests between intervention (VPS) and traditional (PPT) instructional approaches.

Literature suggests that assessment provides a learning experience and aids in the retention of knowledge (Larson, Butler & Roediger, 2008). The use of MCQ pre-post assessment items was inspired by a study conducted by researchers at the University of Calgary (Coderre et al., 2003). The pre-post measure developed for the current study consisted of two parallel forms, each with 20 multiple choice items. These assessments were administered to students at the beginning and end of a case practice session via ExamSoft™, a web-based assessment system routinely used during course exams. This system randomizes (scrambles) the test answers. Figure 22 presents a sample pre- and post-test item.

Your patient suddenly becomes unconscious and has a weak carotid pulse. Cardiac monitoring, supplementary oxygen, CPR and an IV have been initiated. The code cart with all the drugs and transcutaneous pacer, defibrillator, and cardioversion capabilities are immediately available. Your first action is:

Begin transcutaneous pacing.
Begin vasopressor medication.
Give medication to accelerate heart rate.
Initiate the process of electrical cardioversion.
Place patient in a Trendelenburg position.

Figure 22. A sample pre- and post-test item. Reprinted with permission (SOMA TEAL Team, 2013).

Due to the content requested for the “palpitations workshop” the items were related to the topic of interpreting heart rhythm strips or explaining the best course of action when presented with a heart rhythm in a given emergency scenario. Within each test, half of the items (10) were clinical scenarios, and half were simple identification of heart rhythm. The identification of a heart rhythm is a type of pattern matching.

Pre- and post-test development and validation. Since it was not possible to use previously validated exams, following a literature search I constructed a pre- and post-test validity guidelines matrix (Figure 23). During the assessment development phases for the Field Test (April-May, 2013) and Main Study (November 2013), faculty assessment authors followed steps 1-4. Next, recommended guidelines 5-6 were followed during the test administration phase. Finally, item statistics analyses were performed using SPSS and ExamSoft to document the item reliability, and describe the distribution.

	Guideline	Explanation	Solution
Development Phase	1. Use parallel forms for pre- and post-test.	Using parallel and equivalent but different pre- and post-test forms reduces the testing effect concern that students will simply remember the contents of the first form (Blane et al 1986; Phye, Robinson & Levin, 2005).	For each exam, two parallel forms were constructed by scrambling the item and distracter order of test items.
	2. Ensure that the exams are constructed by faculty certified in National Board of Examiner (NBOME) item writing skills.	When faculty are certified in item writing, this leads to greater item validity (Holmboe & Hawkins, 2008).	SOMA faculty are required to maintain certification in NBOME item writing.
	3. Ensure that the test items meet NBOME criteria for item construction.	The NBOME publishes their criteria for item writing (2011).	Assessment authors followed NBOME criteria for developing case scenario-style items.
	4. Ensure that the test length is adequate for reliability, at least 20 items in length	"...it is much less likely that low achieving students can correctly answer all items on a 20-item test" (Wells & Wollack, 2003, p. 5)	Quizzes were 20 items in length.
Test Administration Phase	5. Alternate the test forms among cohorts. (Phye et al. 2005)	Avoid one group or another from having an advantage due to the order of the exams.	Both groups received the same exam at the same time.
	6. Control for outside instruction interference.	Ensure that outside instruction does not occur in addition to the intervention between pre- and post-test (Phye et al., 2005).	No instruction, aside from the intervention was provided between pre-and post-test.
Data Analysis Phase	7. Review the test results to assess whether the pre-test scores for the two comparison groups were equivalent at the outset. Review the test distributions for normalcy.	• Comparison group scores mean scores should be approximately the same at pre-test. (C. Bay, personal communication, January 24, 2014). • Distributions on the exams should be normal. (Brown, 2011).	Comparison group Session I pre-test means were compared means and determined to be approximate. Test statistics were reviewed for distribution, skew and kurtosis. All were within normal parameters (Appendix Q.)
	8. Assess item reliability using item KR-20 values.	The Kuder-Richardson formula calculates the item reliability (Bodner, 2013).	KR-20's were calculated during item analysis. (Appendix Q.)
	9. Assess item quality using item point-biserials.	An item is considered to be discriminating if the higher performing students tend to answer the item correctly while the lower performing students tend to respond incorrectly (Wells & Wollack, 2003). The item point biserial indicates the item quality.	Item point-biserial statistics were calculated during item analysis. (Appendix Q.)

Figure 23. Guidelines for ensuring the reliability and validity of pre- and post-test instruments.

Two key studies informed the process of developing and balancing of test forms, as described next.

Key study: Pre- and post-test equivalence: Blane, Calhoune, & Vydareny *(*1986) suggest a process for the development of “parallel or equivalent” pre- and post-tests in order to construct an objective measure of learning gain. First, faculty provided a list of objectives (facts, skills and principles, and areas of application) they felt students should master. Next, test developers created a “specifications” matrix with the skills listed down the left side of the table, and the type of item (recall of information, understanding of principles, and application of principles) along the top. Faculty then reviewed all the material studied by the students, and created a set of items. Test developers categorized the items according to objective and item type to ensure the proper weighting had occurred.

The pre-post tests for the current study were prepared by TEAL professors. Following the process set forth by Blane et al. (1986), faculty test authors conferred with course directors on the competencies required for the palpitations scheme. The target competency area was making clinical decisions related to heart rhythms and palpitations. Following this discussions, authors compiled three resources used to develop test items in this genre: Advanced Cardiovascular Life Support (ACLS) Pre-Test (RCP Advanced Life Support, 2011), open source online ACLS practice test items (ACLS Training Center, 2014), and Case Files (Access Medicine, 2014). Test one (20 items) related to heart palpitations that indicated a serious heart condition. Test two (20 items) related to heart rhythms that do not indicate a grave heart condition. To balance forms, I created a matrix of test items by type (interpretation of rhythm strip, or case scenario) and balanced the two forms for each test. For example, both tests 1 and 2 each featured 10 items that related to the competency of interpreting a heart rhythm strip to identify a heart rhythm. The other 10 items included a clinical vignette or asked about medical knowledge associated with a heart rhythm.

Key study: test development. In a 2011 study, Colt, Davoudi, Murgu and Rohani describe the development of pre-post assessments for a one-day bronchioscopy course. The workshop content aligned to prescribed objectives. Course instruction included hands-on activities interspersed with lectures which were designed to teach skills in a sequential, step-wise format. Teaching faculty received instructional guides so they could serve as "personal learning coaches" instead of merely acting as experts with facts and knowledge. Three authors participated in developing a total of 75 MCQ items which related to the bronchioscopy objectives outlined. These items were field tested at the University of California at Irvine, and those questions with "extreme high or low difficulty indices (80% or 20% correct response rate) were eliminated" (p. 206). A total of 40 items remained to develop the pre-post exams. These items were shuffled into two sets to reflect equivalent proportions of easy, intermediate, and difficult among the key test constructs. These researchers reported positive class average normalized gain.

This process of field testing and reviewing response rates informed the current study and confirms that gain may be measured after focused training sessions of short duration. This study outlined by Colt et al. provides a model for measuring learning gain using a pre- and post-assessment after a relatively moderate amount of instruction. Following this model, prior to implementation, assessments were peer-reviewed by the course director.

Equating VPS and PPT cases. The controlled trial for the current (McCoy) study compared two different modalities of instruction. To ensure equivalency of content across the two teaching modalities, the author of the VPS cases "Palpitations 1 & 2" also drafted equivalent PPT cases "A Night in the Telemetry Unit" and "It's Everywhere You Go". These PPT cases were reviewed by the course director and 'small groups' leader prior to the trial.

Equating the VPS cases "Palpitations 1" and "Palpitations 2". Since the crossover design of the pre- and post- test sequence included two different cases, "Palpitations 1 and 2", it was vital that the cases be equivalent in terms of length and content depth (Blane, Calhoune, & Vyardeny, 1986). Prior to their development, these two cases were balanced using the matrix method described by Blane et al. (1986). The cases were designed to be equivalent in length and layout. While parallel in design, each presented a different series of clinical scenarios requiring students to assess patient heart palpitations based on the interpretation of heart rhythm strips.

Case 1 required interpretation of heart rhythm strips and clinical decisions related to patients presenting with threatening heart rhythms, and Case 2, serious or life-threatening conditions. However, students were not pre-informed of this distinction prior to case practice.

Pre-post measure analysis*.* After the students completed the assessments, the school's assessment team downloaded the student assessment results from ExamSoft in Excel format. I worked closely with the university statistician to complete the statistical tests. A mixed, generalized linear models approach was used to analyze this doubly repeated-measures design, with a focus on contrasts of specific interest:

- Interaction of change (pre- vs. post-test) with instructional mode (VPS vs. PPT) for Palpitations Case 1 (Session I): Does learning gain (change score) differ across instructional modality?
- Interaction of change (pre- vs. post-test) with instructional mode (VPS vs. PPT) for Palpitations Case 2 (Session II): Does learning gain (change score) differ across instructional modality?
- Interaction of change (pre- vs. post-test) with modality (VPS vs. PPT) for Palpitations Cases 1 and 2, combined: Does change in score differ across instructional modality for when both Palpitations 1 and 2 cases are combined?

The main effect for Group (A vs. B) was assessed and incorporated in the final contrast. Appropriate covariance matrices and link functions were chosen, depending on the correlations between measures and distributional characteristics of the data. Means and confidence intervals, along with effect sizes were reported for all parameter estimates of interest. SPSS 21 (SPSS, Inc.) was used for the analysis. An alpha of 0.05 was used to determine statistical significance.

Measure 3: Exit survey. A VPS experience Exit Survey was used to answer research questions 1, 3, 4, and 5. This survey included three demographic items (age and gender and a question regarding learning preference via lecture capture), plus an additional 24 questions which measured three main constructs: engagement (8 items), collaboration (8 items), and clinical decision-making (8 items). Per a consensus decision by the TEAL team, this survey employed a

5-point Likert scale to minimize misunderstandings in interpreting the task or scale: *Strongly Agree - 5, Agree - 4, Neutral - 3, Disagree - 2, Strongly Disagree - 1*. Individual survey questions were designed to examine key elements of each construct. The purpose of this survey was to ensure that the learners had the opportunity to reflect on the value of VPS case practice and provide feedback. Figure 24 provides a sample of one of the item sets. Entire survey forms for field test and final implementations are provided in Appendix G.

7. CLINICAL DECISION MAKING. Please rate the critical thinking aspects of the virtual patient simulation activities.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. They provided practice with schemes and inductive reasoning.	○	○	○	○	○
2. They increased my evidence sorting abilities.	○	○	○	○	○
3. They helped me review for exams.	○	○	○	○	○
4. They integrated theory with practice.	○	○	○	○	○
5. During VPS activities, I made decisions about the sequence of the patient encounter.	○	○	○	○	○
6. During VPS activities, I gathered evidence from physical examinations to make clinical decisions.	○	○	○	○	○
7. During VPS activities, I synthesized evidence to prioritize lab and imaging investigations.	○	○	○	○	○
8. During VPS activities, I applied pertinent evidence at each decision point to reason toward a ballpark diagnosis.	○	○	○	○	○

Figure 24. Sample Exit Survey items.

The first item of this item set inquires whether the VPS provided practice with schemes (aka clinical presentation schemes) and inductive reasoning. This terminology was familiar to participants. Each year during orientation, the faculty explains the use of clinical presentation schemes and inductive reasoning.

Development. The survey instrument was developed and validated through a stepwise process**.** Literature searches were conducted to review surveys related to VPS and video games for medical education simulations (Kron, Gjerde, Sen, & Fetters, 2010; Rotgans & Schmidt, 2011, Shieffele & Raabe, 2011). These searches revealed no published survey instruments that completely interrogated the complete range of topics associated with this study and specific educational context. Survey item topics map to key domains: clinical decision-making, collaboration, and engagement (Fig. 25).

Survey Item	Literature
Clinical Decision Making	
Scheme Induction	TEAL Team
Evidence sorting	AACOM, 2012
Preparation for exams	Bilde et al. 2011
Integration of theory and practice	AACOM, 2012
Sequence of patient encounter	AACOM, 2012
Gathering evidence from physical exam	AACOM, 2012
Prioritization of lab and imaging investigations	AACOM, 2012
Application of pertinent evidence toward a diagnosis	AACOM, 2012
Collaboration	
Brain-storming with fellow students	IPEC, 2011
Team discussion clarification of concepts	Aufschnaiter, 2003
Group decision making	IPEC, 2011
Effort	Rotgans & Schmidt, 2011
Working in a small team of 3	Piezon & Donaldson, 2005
Communicating using respectful language	IPEC, 2011
Encouraging others to express opinions	IPEC, 2011
Other group members communicated respectfully	IPEC, 2011
Engagement	
Increased my interest in clinical practice (relevance)	Bilde et al. 2011
Added variety (interest)	Prince, 2004
Provided relevant feedback (relevance)	Bilde et al. 2011
Provided exposure to new experiences (interest)	Prince, 2004
Time awareness (flow)	Schiefele & Raabe, 2011
Enjoyment of working on tasks (flow)	Schiefele & Raabe, 2011
Absorption in activity (flow)	Schiefele & Raabe, 2011
Exciting tasks (flow)	Schiefele & Raabe, 2011

Figure 25. Exit survey constructs.

This process rendered an original survey instrument refined through several iterations of implementation and peer review. This 'VPS Experience Exit Survey' collects data on themes deemed valuable to TEAL team faculty trainers at this education site and students that emerged from the 2012 beta trial and the 2013 field test. The TEAL team reviewed iterations of the 19-item field test version (Appendix G) and provided input regarding the Likert scale. Subsequently, a team of educator colleagues and faculty mentors reviewed each draft. The field test items were healthy, and thus retained for the final study. Eight more items (four for clinical reasoning and four for collaboration) were added to balance the weight of each domain The final form is a 28-item virtual simulation experience exit survey that reflects the unique context of practice, an emphasis appropriate to design-based research studies (Appendix G).

The fall 2013 version of the Exit Survey includes an item regarding learning preference. All lectures are recorded via our lecture-capture system, echo-360.™ During the survey development phase, it seemed important to determine whether students who preferred to study at home via lecture-capture would respond differently to survey items regarding an in-class team lesson than students who attended classes regularly.

Data collection. Both implementations of the Exit Survey (field test and final) were conducted electronically via Survey Monkey™ during required class time. Both survey forms contained an introductory paragraph informing participants that responses would remain anonymous and data would be aggregated (Appendix G). The first item of each survey allows students to exclude their responses from analysis: "I agree that my survey responses may be used for research purposes: Yes/No. For both the field test and main study surveys, after administration, the survey results were filtered to exclude responses any participants who selected "No" to this item.

Data analysis.

Field Test Version, Spring 2013. Survey responses were downloaded from SurveyMonkey ™ as excel spreadsheets. SPSS was used determine inter-item reliability. Item analysis revealed that all of the items contributed to the survey. The Cronbach's α for the field-test survey was .934 (item N = 18), reflecting a high degree of reliability (Salkind, 2010).

Final Version, Fall 2013. Survey responses were downloaded from SurveyMonkey as Excel spreadsheets. SPSS was used to determine inter-item reliability. Cronbach's Alpha reliability estimates provided construct sub-scale reliability, as follows:

- Clinical Decision Making scale (α =.868), participant n=103, item n=8.
- Collaboration scale (α =.866), participant n=103, item n=8.
- Engagement scale (α=.882), participant n=103, item n=8.

According to Salkind (2010) alpha values higher than .8 reflect a very good level of reliability.

Measure 4: Transcription of VPS and traditional case discussions. To answer research question 2, the study included analysis of student dialogs during VPS and traditional case instruction.

Data collection. In order to study student discussion during different modes of instruction, the study included classroom observation and video-recording of six small group rooms for each of four separate practice sessions. This was accomplished using the school's 'small group' classroom auto-recording system, Arcadia™. While all small group rooms were monitored and video-recorded during each practice session, it was not feasible to transcribe 33 student conversations per session. As a result, one student VPS conversation would be transcribed for each of four sessions. Protocols outlined by Taylor-Powell and Steele (1996) for structuring a sampling procedure guided the decision to use random sampling to increase validity. Whichever tutor was assigned by the third year coordinator to the key observation room asked for three volunteers among ten of their students to go into the adjoining room, complete a VPS. Four traditional case practice sessions were also selected for transcription. During the fourth session, although I observed a triad of students completing a simulation, the video recording system failed to record. Therefore, in order to analyze a total of four separate VPS sessions, I transcribed a separate second VPS session from the third practice session.

Transcription analysis. For each of the sessions previously mentioned, I accessed the videos online and transcribed the first half hour of VPS case practice, plus an additional half hour of traditional small group instruction. I constructed the transcription records according to protocols outlined by researcher Weber (K. Weber, personal communication, September 21, 2012) by accurately labeling the transcription documents, inserting time stamps, and consulting medical dictionaries regarding medical terms. I also inserted screen captures from the VPS into the transcription documents in order to better follow and interpret the student dialog. In some sections of the transcriptions, depending upon the location of the microphone in the room, some of the exact words of the student's sentences were muffled. I replaced these missing words with ellipses. Despite this sound constraint, the transcriptions revealed the topics and tenor of the discussion. I sent the transcriptions for review or 'member checking' (Stake, 1995) to the small group or VPS case author associated. Some responded with minor comments, but none returned corrections regarding the transcription.

To strengthen analysis, allow for data mixing, and provide an audit trail, MS Word documents with narrative data such as transcriptions of dialog and observer memos were uploaded to HyperResearch™3.5.2. This software allows the researcher to tag segments of text using an open coding process (Corbin & Strauss, 2010I). The next step was to associate the codes with five *a priori* domains: clinical decision making, engagement, collaboration, tutor interaction, and the VPS activity (See Appendix R). HyperResearch-generated summary reports listing codes and data sources were exported into Excel spreadsheets. Data were distributed to separate worksheet tabs according to domain and sorted the data by traditional, VPS, or transition modes instruction. Finally, in order to study the relative range and frequency of themes, the frequency of codes (data instances) were tabulated, aggregating across the four sessions observed.

Measure 5: Tutor feedback form. To answer research questions 1-5, data were collected using the Tutor Feedback Form (Fig.26). Six tutors facilitated four VPS sessions, each overseeing approximately ten students. During the sessions, each tutor observed the students as they completed VPS, and remained available to answer questions. During the tutor preparation session prior to each session, I reviewed the purpose of the feedback forms with tutors, and encouraged them to submit comments. After each session, many tutors wrote optional, hand-written observations on paper forms and submitted them to a third-party curriculum coordinator.

VP Sim Tutor Instructions

1. Today the students will be completing a 20 minute virtual patient simulation case.
2. During these simulation exercises, your role is "Guide on the Side".
3. Please feel free to circulate among the students.
4. Please only answer questions as asked, but do not give the answer. Direct them to information which will help them make the decision.
5. Please be brief, and allow the students to move through.
6. Students are allowed to take notes during the case.
7. It is ok if students do not complete the entire case.
8. At the end of the session, student teams will complete a "Diagnosis Competency Task".
9. Please do not help them complete the task.
10. Students should place the completed task worksheet in the envelope provided.
11. This envelope is extremely important and should be returned to the Year 1 Coordinator.
12. After the competency tasks have been submitted, please lead a 10-minute debrief regarding the case using the discussion questions provided, but do not allow students to change their answers on the competency task.
13. In the comments section below, you are invited to reflect on how to improve this sim.

Tutor Feedback Form

Decision Sim Case: ________________________ Date: _______________________________

Comments:

Figure 26. Tutor feedback form.

Data analysis. The process of analyzing tutor feedback began with reading through the anonymous comments, and typing each comment into a compilation text document. In between simulation sessions, the TEAL team met to discuss the de-identified tutor feedback to determine whether there were technology glitches or issues to address. Following the same process outlined above, tutor feedback data were coded and analyzed using HyperResearch.

Measure 6: VPS implementation session observation form. To collect additional data regarding the VPS mode of instruction, I developed a Session Observation form. This form was refined through peer and TEAL team review (Fig. 27).

VPS Implementation Session Observation Form

Decision Sim:	**Date:**	**Observer:**
Time of Observation	**Room Observed:**	**Session A** ☐ **Session B** ☐

Lesson Dimension	**Observations**
Tutors were briefed prior to the lesson. **Y** ☐ **N** ☐	
Tutor interactions are per design. **Y** ☐ **N** ☐	
Student team configurations are per design. **Y** ☐ **N** ☐	
Students accessed the case successfully. **Y** ☐ **N** ☐	
Students appear to be focused on the lesson. **Y** ☐ **N** ☐	
The competency task exercise was executed per design. **Y** ☐ **N** ☐	
Unforeseen events occurred. **Y** ☐ **N** ☐	

Plan to Improve Next Implementation

Figure 27. *Session observation form.*

Recording researcher observations during VPS practice sessions served two purposes: 1) to document whether sessions were implemented as planned (with fidelity) and 2) to identify facets of the lesson plan to improve, related to the research question, *Which design elements of this intervention need to be revised for the next implementation*? DBR expert Brenda Bannan-Ritland (2003) urges design based researchers to develop tools, artifacts, and processes to characterize and document the hundreds of decisions made during the design process. Applying this concept to the implementation phase, one goal of this study was to chart key decisions regarding implementation of the virtual simulations in classrooms during the practice sessions, using iterative feedback cycles. During each VPS session, I took notes on observation forms and these notes were used to ensure that subsequent sessions would run more smoothly.

Data analysis. The grounded theory process suggested by Corbin and Strauss (2010) entailed reading through these objective observation notes and allowing them to serve as a writing prompt for a more subjective and reflective 'researcher analysis memo' about the experience. The Session Observation notes and analysis memos were typed, uploaded HyperResearch, and open-coded. This process rendered Excel spreadsheets for each domain associated with this study: clinical decision making, collaboration, and engagement, VPS intervention.

Measure 7: Photographs of classroom sessions. Constructing a visual gallery of student groupings and external evidence of engagement involved taking photographs of video recordings of classroom activities during both intervention and control instructional modalities. Digital ethnographer Pink (2007) asserts that it is important that the researcher identify the purpose of the data collection and document the underlying ethos (ethics). There were two reasons for collecting photographic data. First, it was important to document the design case with a rich digital record of the event happening simultaneously in six concurrent classrooms. Second, to increase the validity of study via data triangulation to analyze the photographs for outward signs of collaboration and engagement.

Ethos. One ethical imperative was to protect the privacy of the subjects. Tutors provided a printed explanation of the study that pre-informed the students they would be video-recorded and photographed. This form explained that digital images that could identify participants would not be shared in a publication format without their express written consent. Another ethical objective, related to validity, was to make an effort to “see” the data more objectively than by simply viewing video and selecting important moments to screen capture.

Data collection. During the four VPS practice sessions, professors randomly selected a team of three students to move into a small group room to talk without sound overlap from other teams. During the sessions, I observed remotely from the control room, primarily observing the isolated team working the case. At designated intervals, I made a complete round of all six computer recording stations recording each of the small group rooms. Since each small group classroom was outfitted with two cameras, I collected two photographs at each station (Fig. 28).

Figure 28. A control room classroom observation station. Printed with permission (SOMA TEAL Team, 2013).

In Figure 28, the faces of the students and instructor were intentionally blurred to obscure identities. The pre-documented randomized, scientific approach to collecting digital images during this study entailed taking a round of photographs at ten minute intervals (30 minutes VPS and 30 minutes traditional small group instruction).

***Data analysis*.** Digital ethnography expert Sarah Pink (2007) writes that “a realist approach” to coding complex visual data offers a crucial means of managing data and triangulating findings (p.124). Data analysis unfolded in three steps, described next.

1. The organization of the digital library. After downloading 295 video images from the iPad, image data were stratified into electronic folders for each date of data collection by sequence and modality of instruction: “VPS, Transition, and Traditional Instruction.” The photographs were open coded by hand instead of uploading them to HyperResearch since these data were not mixed using the HyperResearch database. Within the digital archive, each photographic file was labeled with a discrete numeric designation. During the process of open coding, each photograph was referenced by numeric designation.

2. *The development of codes for photographic data analysis.* According to Pink, one method of digital analysis is to open code the photographs to discover themes. Pink (2007) cautions that in analyzing photographic data, there is always an element of subjectivity. In order to mitigate the subjectivity, code descriptions (Appendix R) reflected objective body behavior, such as leaning in. Codes grouped into categories and themes mapped to the *priori* domain, ‘engagement’: *highly engaged*, *engaged and leaning in*, *interactive, focused on task*, *transition activities*, *passive listening*, *low enthusiasm*, and *closed.*

3. Interpreting body language through photographs. The team based learning for healthcare professions literature describes body language such as leaning in, communicating effectively, and not engaging in off-task behaviors such as checking email (Michaelsen, Parmelee, McMahon & Levine, 2008). Westberg and Jason (2004) describe the non-interactive student behavior during authoritarian small group participation as “distant and guarded.” Additional literature on the interpretation of body language arises from the business fields in relation to corporate meetings. This body of popular wisdom concludes that body language such as slumping down or learning on the table, lowering the head or lack of brightness in the eyes while listening passively (glazed expression), or crossing the arms indicate boredom or reservation. Using this body of theory as a basis, I watched the slide shows of the photograph data, developed a list of initial codes that I reviewed with the TEAL team so they could assess the range of codes to ensure none were overlapping and all were defensible. They suggested I use codes toward objective categorization of physical body movements.

Research Plan, Main Study

Final Implementation

Following DBR principles of iterative improvement, results from the first implementation phase informed and improved the design of the second phase, the main study (October-December 2013), which repeated the study data collection sequence (Fig. 29).

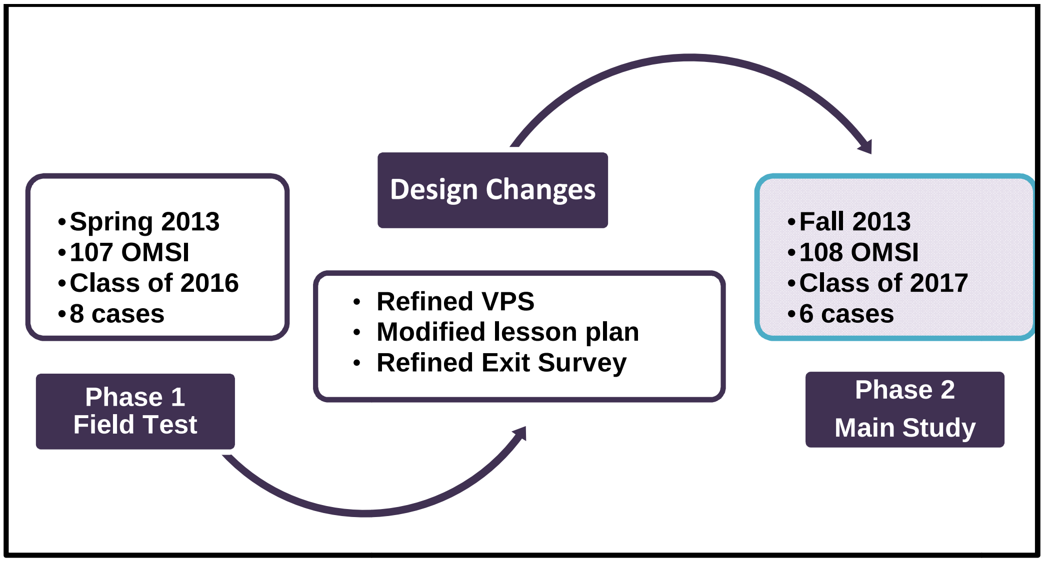


Figure 29. *Phase 2, final implementation*

Fall 2013 VPS cases. Phase 2 included total of six VPS cases. TEAL team faculty had developed VPS on the topics of Limb Pain, Seizure, and Dizziness, and beta tested them in the fall of 2012 (Appendix H). These cases were updated and re-used for the fall 2013 study. In addition, case authors created a new VPS on Regional Back Pain, and two new cases on the topic of heart palpitations.

The classroom environment. Figure 30 contrasts the breakout room configurations for traditional and intervention sessions.

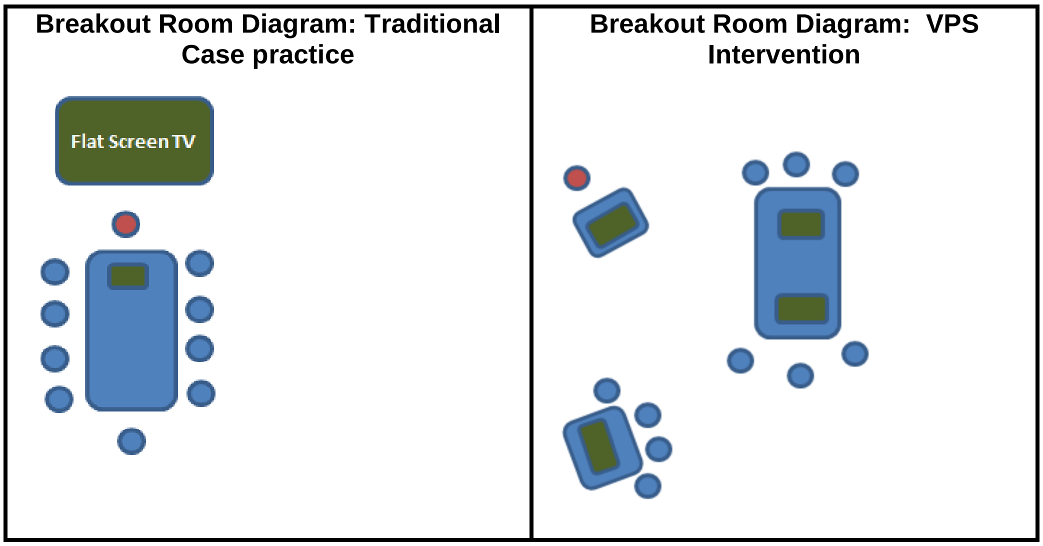


Figure 30. Small group room configurations for sessions 1-4.

In the traditional small group diagram, the large green rectangle represents flat screen TV and the small green rectangle represents the tutor's laptop. The red dot represents the tutor, the blue dots, students. During traditional case practice, depending on the tutor, either the tutor or the students commanded the mouse while discussing the case on a PowerPoint projected on the flat screen. In the intervention diagram, student teams of 3-4 commanded the mice, as well as the pace of the VPS lessons via their own laptops. During VPS sessions, the tutor was present, circulating among students, but did not lead the case practice.

VPS sessions. There were five VPS sessions during the second implementation.

Session 1 (October 7, 2013). Prior to case practice on Fridays during the NMsk course, six case facilitators (tutors) attended a briefing session. During this session, I briefed tutors on how to introduce the study and facilitate the VPS case practice. (See Appendix N). After this briefing of tutors, the students arrived for class, and the tutors moved to breakout (small group) classrooms to meet with approximately 10 students apiece. Half of the student sample (Cohort A) arrived for their case practice session at 1 pm. This group of 54 students was distributed to six break-out rooms, each supported by a physician-tutor for a two-hour case practice. This initial session lasted 2 hours and included three cases. First, each tutor read the *Study Explanation* to students. Next, students arranged themselves into triads (groups of three or four), and using one student laptop among the three, student teams guided themselves through the 20 minute VPS case on the topic of Limb Pain. Tutors circulated and answered questions if requested. After 20 minutes, student teams completed a Diagnostic Competency Task via paper. Next, students placed the Task document to a collection envelope. The envelope was returned at the end of the session to the year 1 curriculum coordinator. Tutors conducted a 10-minute session debrief based on a handout following the on-line VPS case. During each session, one of the tutors requested 3 student volunteers to move into a separate small group room to enhance the sound quality of the recording.

During each VPS session, I observed all six of the small group rooms via remote camera from a control room in order to verify the fidelity of the lesson plan. I took notes on the Session Observation form. I also took photos of each small group video image every ten minutes using an iPad. All the small group sessions were video recorded through the school's video recording system, Arcadia^{TM}. The video recordings captured both the VPS and traditional instruction for each session. Following each session, I transcribed one 30-minute isolated team discussion from the video recording as well as the subsequent 30-minute traditional case session led by tutors.

Session 2 (October 15, 2013). The entire cohort of students participated in a VPS on Friday on the topic of Regional Spinal Pain. Students worked collaboratively in teams of three to complete a 20 minute session via laptop. At the end of the case, each team completed a Diagnosis Competency Task via paper. Each student team placed the Task document in an envelope delivered to the year 1 coordinator at the end of the session. The tutors circulated and answered questions if requested. They also held a 10 minute session debrief following the on-line lesson. I observed activities in this session via video camera to verify the fidelity of the lesson plan. During this observation, I took field notes using the Session Observation Form. I photographed each small group video image at ten-minute intervals. All sessions were video-recorded. Afterwards, one VPS session and one traditional session were randomly selected for transcription.

Session 3 (November 8, 2013). The entire cohort of students participated in a VPS on Friday on the topic of Seizure. At the end of the case, student teams completed a Diagnosis Competency Task via paper. Each student team placed the Task document in an envelope returned to the year 1 coordinator at the end of the session. The tutors circulated and answered questions if requested. Next, the tutors led 10 minute debriefs regarding muddy concepts encountered during the on-line VPS lesson. I observed activities in this session via video camera to verify the fidelity of the lesson plan. During this observation, I took field notes using the Session Observation Form and photographed each small group room at ten-minute intervals. The sessions were video-recorded. Afterwards, one VPS session and one traditional session were randomly selected for transcription.

Session 4 (November 15, 2013). The entire cohort of students participated in a VPS on Friday on the topic of Dizziness. At the end of the case, student teams completed a Diagnosis Competency Task via paper. Each student team placed the Competency Task document in an envelope returned to the year 1 coordinator at the end of the session. The tutors circulated and answered questions if requested. They also held a 10 minute session debrief following the on-line lesson. I observed activities in this session via video camera to verify the fidelity of the lesson plan. During this observation, I took field notes using the Session Observation Form. I photographed each small group room at ten-minute intervals. The sessions were video-recorded. Afterwards, one VPS session and one traditional session were randomly selected for transcription.

Session 5 (December 18, 2013). The entire class of first year students participated in an Exit Survey regarding their experience with the virtual patient simulations. Students received the web link to their 10 minute online Exit Survey at the outset of this session. Following are instructions provided to the students prior to the survey:

1. As part of normal, required case practice activities, please complete a 28-item survey.
2. Responses to this survey are anonymous.
3. Responding to this survey will not affect your grade.
4. The responses from this survey will be aggregated and used for improving instruction.
5. Some of the comments may be reported in an anonymous format in research reports.

This activity was scheduled during a required case practice time to ensure a sufficient response rate. Survey responses were anonymous. The first item of the survey provided students the option to decline the use of their responses for research.

Next, the entire cohort of students participated in a randomized, crossover trial. Figure 31 displays events during on the crossover sequence. The first year coordinator randomly assigned students into two stable batches (Cohorts A and B). Cohort A (Galen) reported to the large group classroom (Cougar). Cohort B reported to a separate large group classroom (Owl).

Cohort A 'Galen' (n=54)		**Cohort B 'Hippocrates' (n=54)**	
Session 1	Session 2	Session 1	Session 2
Pre-test 1 Individual 20 MCQ 20 minutes	Pre-test 2 Individual 20 MCQ 20 minutes	Pre-test 1 Individual 20 MCQ 20 minutes	Pre-test 2 Individual 20 MCQ 20 minutes
Intervention Case VPS Palpitations 1: Not Serious 20 minutes	Traditional Case PPT "Palpitations 2" Serious Palpitations 20 minutes	Traditional Case PPT "Palpitations 1" Not Serious 20 minutes	Intervention Case VPS "Palpitations 2" Serious Palpitations 20 minutes
Post-test 1 Individual 20 MCQ 20 minutes	Post-test 2 Individual 20 MCQ 20 minutes	Post-test 1 Individual 20 MCQ 20 minutes	Post-test 2 Individual 20 MCQ 20 minutes

Figure 31. Randomized trial: Effects of teaching modality.

Cohort A students (n=54). For the first hour of case practice, these students individually completed a 20 minute, 20-item multiple choice pre-test via ExamSoft, followed by 20 minutes of group case instruction in the VPS method, followed by a 20-item post-test.

Cohort B students (n=54). Concurrently, Cohort B students (n=50) individually completed the same 20 minute test taken by group A, and studied the same case in a different instructional modality, the in the traditional (PPT) "control" method, led by a live instructor, followed by a 20-item, 20 minute post-test. Figure 32 provides a Pre-Post Sequence Map. The cohorts remained constant between sessions 1 and 2.

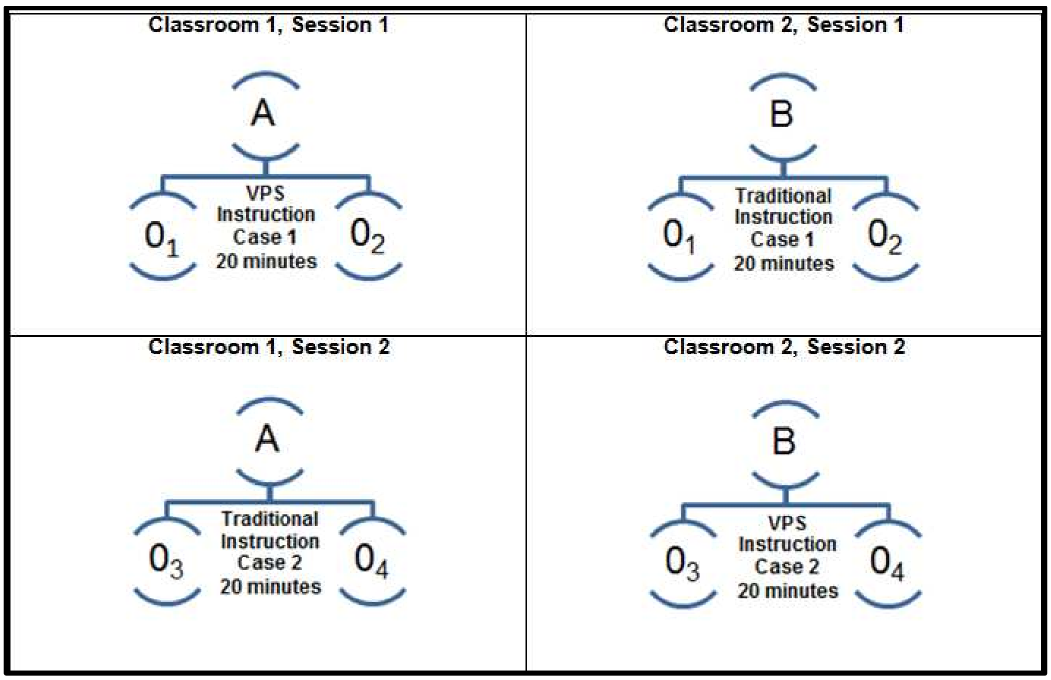


Figure 32. Pre-post sequence map. 0_1 = pretest and 0_2 = post-test 0_3 = pretest and 0_4 = post-test. See Appendix O for the instructions to the students in advance of the pre- and post-tests.

Theory Development

'Grounded Theory' Protocols

Coding and categorizing qualitative data. Qualitative data included survey open responses, tutor feedback, researcher observations and memos, student discussion transcriptions, and photographs. These data were processed and analyzed following grounded theory protocols outlined by Corbin and Strauss (2010). This involved:

- Reading through the transcribed responses sentence by sentence to open code concepts (such as “enthusiasm”).
- Creating separate codes to indicate variation in the dimension of the code such as “degree.” For example, if a code is enthusiasm, an opposite might be boredom.
- Organizing the codes into wider categories and *a priori* domains such as “collaboration” using *HyperResearch.*
- Requested the TEAL team verify the codes and categories.
- Developing a code book which defines the scope of each code (Appendix R).
- Developing a research document blueprint that lists the locations and file names of all the research documents.
- Using graphic organizers to compile quotations from raw data into generalized descriptions and illustrative examples.

Analyzing qualitative data. Qualitative researchers Glaser and Strauss (2011) explain: “In generating theory, one generates conceptual categories or their properties from evidence; then the evidence from which the category emerged is used to illustrate the concept” (p. 23). Corbin and Strauss (2010) assert that analysis is the building block of (micro) theory construction. Following methodology outlined by these researchers, I employed microanalysis to find associative interconnections between phenomena as they informed the domains including (but not limited to) clinical reasoning, engagement, collaboration, and VPS activity implementation. This involved ‘memoing’ after thinking through possible meanings of words and phrases. For example, if students mentioned the desire for tutor input, I considered whether that precluded an interest in peer collaboration.

Deriving the central phenomenon. Analysis began with the process of reading through the data (dialogs, photos, observations, and analysis memos) as prescribed by Corbin and Straus (2010). Next I diagrammed the sequence of the events and discussion topics revealed through student encounters with four patient cases. This sequence was analyzed to discover a narrative (story) linking the commonalities among all four cases. As the story emerged, it revealed a metapattern. Corbin and Strauss (2010) construe this core theme as “the central phenomenon”.

Design-Based Research Protocols

Developing Petite Design Generalizations. DBR research studies generate contextually-based theories called “Petite Generalizations” (Barab & Squire, 2004). According to DBR expert Sasha Barab, petite generalizations are not simply bare research findings (personal communication, March 12, 2013). They are outfitted in a rich, thick description of the constraints and conditions which provide other researchers enough information about the precise context in which the research was conducted to assess the applicability of the findings to their own contexts. In the following study, researchers describe the process of triangulating data to assert petite design generalizations.

Key study: The Science Apprenticeship Camp. In this 2001 DBR study, Barab and Hay analyzed naturalistic data to gain a ‘holistic vision’ of the effectiveness of a novel mode of science instruction. In this study, researchers grouped 24 middle school students into teams of 4 to learn to practice science ‘at the elbows of scientists’ in a science apprenticeship camp. Researchers presented hypotheses in the form of six pre-defined characteristics of their innovative science camp, and then tested whether those six characteristics were actualized by collecting qualitative data through field notes, video recordings, student presentations, semi-structured interviews, and researcher observations. These researchers reported their petite theories narratively, organized by characteristic, using rich descriptions, providing examples of different features and mechanisms within the lesson, and illustrative quotations from students and faculty. For example, one of the key learning characteristics was *“Scientific and technological knowledge/practice are situationally constructed and socially negotiated.”* To warrant this assertion, researchers provided screen captures of student PowerPoint presentations as evidence that the students were co-constructing knowledge. Researchers also provided two pages of transcriptions of student conversations.

The authors reviewed incoming data daily during the 10-day camp and made implementation adjustments according to the constant comparison method (Corbin & Strauss, 2010). This research procedure is an example of the DBR iterative feedback cycle allowing instructors to adjust the lesson according to incoming data. This study underscores the importance of data triangulation, screen capturing game pages as students negotiate them, transcribing dialog, and triangulating these with video recordings of student interactions. While petite generalizations such as these were generated as hypotheses supported through qualitative analysis, they were not described as such in this research report. However, in a subsequent work by Barab and Squire (2004) they were referenced as petite generalizations. In their classic journal article describing the attributes of design based research, Barab and Squire (2004) explain:

> Design based research requires more than simply showing a particular design works, but demands that the researcher move beyond a particular design exemplar to) generate evidence based claims about learning that address contemporary theoretical issues and further the theoretical knowledge of the field. (p. 6)

To illustrate this point, authors cited a list of case studies, including Keating, Barnett, Barab and Hay's (2002) DBR report on a 1998 study, "The Virtual Solar System Project."

Key study: The Virtual Solar System Project. In this study, subjects were eight undergraduate students enrolled in an introductory astronomy course in 1998. During this course, instructors divided the students into teams of three and tasked them with generating 3-D virtual models of the solar system using Virtual Reality Markup Language. Students used a graphics editor that allowed them to create objects and drag them around on the screen. To generate petite generalizations, Keating et al. first raised two questions:

1. "What is the conceptual understanding of eight students enrolled in a VSS course?" (p. 264)
2. "What type of conceptual understanding does 3D modeling facilitate?" (p. 264)

Students were interviewed prior to the intervention (the solar system unit) and after the intervention. The interview questions were as follows:

1. "Can you draw the position of the Earth, Moon, and Sun when we can see a Full

Moon, New Moon, and a lunar eclipse from the earth? Describe the differences and similarities between a full moon and a lunar eclipse." (p. 265)

2. "Reasons for the seasons: What causes the seasons of the Earth? Draw a diagram that shows the different seasons." (p. 265)

The student pre- and post-interviews were video-recorded and transcribed; two raters scored the transcribed interviews and rated student responses using a rubric with a scale of 0-4, 0 = No conception, 1 = Confused, 3 = Partial understanding, 4 = Complete understanding (p. 266).

On the eclipse task, student scores increased significantly from 1.69 to 3.56. The one student who did not score well was the student who was using the program to create the model, while the other two students constructed the model by studying dynamics. On the seasons task, student scores increased significantly from 1.4 to 2.81. Limitations of the study included a low number of student participants. Authors also explained that the software constraints and the organization of the project may have limited conceptual understanding. For example, the software's modeling program did not accurately present the exact way the sunlight hits the earth.

According to Barab and Squire (2004), this study generated "…claims about project-based learning and cognition as situated, particularly relations among learner's intentions, tools, and meaning making" (p. 7). In terms of petite design generalizations, authors made two claims about 3D technology. 1) It has the potential for improving student learning, particularly when students are asked to understand concepts predicated on 3D spatial relationships. 2) It provides the means to construct concrete representations. However, they might not be as useful for all situations.

Developing Petite Design Theories for VPS

DBR expert Edelson (2002) categorizes the theories that emerge from iterations of design research as 1) learning activity theories, 2) design theories, or 3) basic theories about student motivation. In a personal conversation with DBR and education game expert Sasha Barab in March 12, 2013, he indicated that in terms of education game innovations, it is common to form theory regarding game or virtual simulation design called “design theory”. For example, a game designer uses classroom experiments to develop theory surrounding the process whereby the game mechanics (the exact tasks in the education game) lead to specific skill outputs—such as key decisions in the game.

Prior to conducting the study, the design intention was that the VPS would afford students opportunities to assemble evidence to make key decisions in the case. Following a protocol familiar from grounded theory, precise petite generalizations are not stated *a priori* as hypotheses; they emerge from the analysis of the data (K. Wetzel, personal communication, November 27, 2013). Research question 2 concerned the exact VPS mechanics that enabled students to make accurate clinical decisions in the VPS. Following models described in the key studies referenced earlier, I generated petite design theories by triangulating data among, student dialog, researcher observations, and tutor feedback.

Validity, Credibility, Reliability, and Trust

The design and implementation of this study adhered to reliability, validity and ethical guidelines for quantitative, qualitative, and mixed design-based research. The sequential, two-phase study adheres to the design based model (Barab & Squire, 2004), while data triangulation through mixed methods increased the credibility of the study findings (Stake, 1995).

Quantitative Methods

The reliability of the quantitative results of this study were verified through statistical analysis using SPSS. The development of the data collection instruments is detailed prior. These instruments were field tested in 2013. The design of the pre-and post-test crossover study design attempted to avoid threats to validity (Creswell, 2009; Willson & Kim, 2012). (See Fig. 33). Limitations of the study are reported in Chapter 7.

Threat To Validity	Steps Taken to Avoid Threat
Testing sensitization Refers to a cognitive or psychological change in a subject due to administration of a test or observation of the subject.	While the pre-test and the post-tests included identical MCQ test items, for each form, they were presented in different order, and the answer choices were presented in a scrambled order. This alleviated the possibility of students memorizing the questions from the pre-test. Students did not receive the answers to the pre-test before they took the post test, and faculty proctoring were not privy to the pre- and post-tests.
Instrumentation Refers to a potential threat posed by variation or non-equivalence of the instruments.	This study's pre and post-tests were of equivalent type, length, and level of difficulty because they shared the same test items, presented in different order. The research timeline precluded creating and balancing equivalent test forms through item statistics.
Concurrent history Concurrent history errors occur if unforeseen events happen during the instructional period to affect the post-test scores.	During the crossover study, only a half hour passed between pre- and post-test. No unforeseen events occurred during the implementation of the examinations except on test item image was absent. This item was omitted from analysis for all participants. Prior history was not an issue because all participants received the curriculum prior to the crossover study. However, there was no incentive for scoring highly. Some students may not have tried very hard.
Maturation Refers to the possibility that participants may mature during the experiment due to input other than the intervention.	During the crossover study, the data collection window was narrow. The study participants had very little time to mature from accessing other course materials outside the immediate intervention or control lesson plans.
Nonequivalence The study design should ensure that the conditions were similar for both groups.	In this crossover design, both groups partook equally of intervention and non-intervention instruction. As a result, there was no non-equivalence issue between comparison groups. During the competency task, all student teams were provided with the same task, and the same time limit.
Regression A tendency for subjects with extreme scores to regress toward the mean on subsequent tests.	In this study, all members of the cohort were assessed. The matter of selection of participants with extreme scores was not an issue.
Mortality Refers to a condition when participants drop out of the study.	This study took place during required participation in-class hours to avoid mortality due to absenteeism.
Hawthorne effect Refers to a condition when participant behavior changes as a result of being informed of being observed.	The Hawthorne effect was mitigated in this study since the exact same conditions were set for both intervention and non-intervention activities. The students were used to being formally observed in many courses and events so they were not overly sensitive about being observed daily.
Novelty effect Refers to a condition when participants rate impressions of a new learning modality higher because it is novel.	For this cohort, prior to the exit survey, the students participated in four VPS over a two month period. At the time of the Exit Survey, simulations were no longer novel.
Experimenter effect An experimenter effect could occur if a specific tutor or instructor provided different instruction.	During session 5 (the comparison, crossover study), all participants received the same instructions, and traditional instruction from the same instructor. During practice sessions 1-4, tutors were requested to refrain from assisting students in completing the Diagnostic Competency Tasks.

Figure 33. Validity protocols, pre-post assessment. Graphic: McCoy. 2013 developed from concepts in Creswell (2009) and Willson & Kim (2012).

Qualitative Methods

This study incorporated elements of rigor associated with validity, reliability, credibility, and trust for qualitative studies (Stake, 1995; Corbin & Strauss, 2010).

Validity. To increase the democratic validity, this study sought participation from stake holders beginning with a problem statement validated by the steering committee, and ending with results presented to a “Stakeholder Review of Study Findings”. In an effort to assure robust instrument validity, qualitative data collection instruments and processes were peer and expert-reviewed.

Credibility. Data were triangulated among seven data sources to increase the credibility of the findings. A process of constant comparison (Corbin and Strauss, 2010) was used to revise the instruments and innovation following data collection cycles. Quality DBR studies should generate local design theories (Barab & Squire, 2004) derived from rich data analysis. Other DBR experts assert that rigorous DBR studies must provide a robust description of the process of design, culminating in a ‘design case’ useful to innovation developers (Edelson, 2002). The current study attempts to provide both.

Reliability: The methods section documents processes for data collection and analysis, such as outlining the methods for collection of digital data and the sampling procedure for analyzing student dialogs. This study employed time-tested methods of grounded theory from Corbin and Strauss (2010) such as open and axial coding, the “implementation fidelity” checklist, a research journal, researcher memos, diagrams, and narrative summation. Three cycles of research increased the reliability of the findings.

Trust. Ethics of the study were vetted through the TEAL team, and through the IRB approvals of two institutions. Specific methods were used to increase the transparency of the data audit trail. These included providing descriptions of codes in the code book, a detailed description of the data analysis process, member checks, and data analysis via HyperResearch software.

Methods Review

This mixed-methods, sequential, design based research study took place at SOMA, a medical school in the southwest United States. This project was registered and exempted with the local education site IRB in April, 2013 and approved by the ASU IRB in May, 2013. Participants were 108 first year medical students and six of their clinical tutors. This study explored the utility of an innovation—virtual patient simulations (VPS) for increasing medical student clinical reasoning skills, peer collaboration, and engagement.

This research study sought answers to five key questions:

1. For undergraduate medical students, year 1, to what extent does deliberate practice with virtual patient simulation improve skills in clinical decision-making?
    a) Student teams will demonstrate competency in clinical decision-making as measured by accurately completing 4 diagnosis performance tasks.
    b) Students agree that VPS are valuable for practicing clinical decision-making.
    c) VPS are effective for improving clinical decision making, as measured by a significant difference in mean gain between pre-and post-tests.
    d) VPS are more effective than traditional case PPT's for teaching clinical reasoning skills as measured by a significant difference in mean gain between pre-and post-tests.
2. Which VPS mechanisms allowed the students to effectively make clinical decisions?
3. In which ways do VPS foster peer collaboration?
4. In which ways do VPS foster engagement?
5. Which design elements of this intervention need to be revised for the next implementation?

The SOMA TEAL team faculty developed six VPS used for the current study in 2013. Designed for novice medical students, these VPS afforded the opportunity for students to manage a patient encounter and render a ballpark diagnosis. During weeks 1-4, the students participated in case practice via VPS as part of mandatory classroom activities. The sessions were proctored by tutors who observed student teams and provided comments via a Tutor Feedback form. During these weeks, I observed the sessions via remote camera and took notes on a Session Observation form. During session 5, students completed an exit survey online during class time and also participated in an equitable, non-graded randomized experiment comparing the effects of two instructional modalities.

Using a mixed methods approach, quantitative measures were used in conjunction with qualitative data collection instruments to triangulate findings. The seven data sources were: Diagnostic Competency Tasks, Pre- and Post-tests, Exit Surveys, Transcriptions of student dialogs, Session Observation Forms, Tutor Feedback Forms, VPS screen captures, and session photographs. In this study, the independent variable was the mode of instruction. The dependent variables were learning performance or gain in clinical decision making, collaboration, and engagement. Data analysis of quantitative data included the use of SPSS to run statistics. Data analysis of quantitative data employed techniques from grounded theory.

Chapter 5 - Results

Introduction

Chapter 4 provided an overview of seven data sources and information related to the development, collection methods, validity and data analysis process for each instrument. This chapter reviews the results from each data source, quantitative and qualitative, in order of data collection. Chapter 5 presents the answers to each of the five research questions. This chapter is divided into three sub-sections: Section 1: Quantitative Data Results, Section 2: Qualitative Data Results, and Section 3: Results Summary.

Section 1: Quantitative Data Results

This section presents results from three data sources: the Diagnosis Competency Task, the Exit Survey, and the Pre- and Post-tests.

Diagnosis Competency Task Results

During the NMsk course (October-November 2013), 108 first year students participated in four practice sessions featuring four, 20 minute virtual simulation cases. After completing the VPS cases, student teams of 3-4 submitted competency tasks related to each case diagnosis. Table 2 provides the percentage of teams who correctly completed the task for each case. These data relate to hypothesis 1A: Student teams will demonstrate competency in clinical decision-making as measured by accurately completing four diagnosis performance tasks.

Table 2

Diagnostic Competency Task Performance by Clinical Presentation Case Topic

Day	Case Topic	# of Student Teams	Competency Task % Correct
10/7	Limb Pain	35	83%
10/15	Regional Back Pain	33	97%
11/8	Seizure	36	88%
11/15	Dizziness	36	100%
	Mean	35	92%

The data in Table 2 indicate that after playing through these four VPS, student teams were able to successfully arrive at ballpark diagnosis for four different patient cases with an average accuracy rate of 92%.

VPS Exit Survey Results

On the fifth and final session of the field test, 106 students participated in an electronic survey during class hours. The exit survey response rate was 97%, since one student declined sharing responses, one participant arrived late, and one did not submit a survey. Survey respondents (n=105) were 50.5% male and 49.5% female. They reported their ages as 20-25 (67.6%), 26-30 (26.7%), and 31-35 (5.7%).

Learning preference: in person vs. lecture capture. As described in Chapter 4, the Exit Survey contained an item regarding student learning preferences in terms of lecture capture. As summarized in Table 3, results revealed that approximately half the students (50.9%) were habituated to studying via echo360 recorded lectures from home.

Table 3

Learning Preference in Terms of Lecture Capture (Echo-360)

	n	%
I always rely on Echo360 for lecture content instead of attending lectures.	12	11.5
I mostly rely on Echo360 for lecture content and sometimes attend lectures.	41	39.4
I sometimes rely on Echo360 for lecture content in addition to attending most lectures.	31	29.8
I rarely rely on Echo360 for lecture content since I regularly attend lectures.	20	19.2

N = 104

Participants reported their learning preferences in terms of lecture capture (Echo360) as follows: “I rarely rely on Echo360” (19.2%), “I sometimes rely on Echo360 in addition to attending most lectures” (29.8%), “I mostly rely on Echo360 and sometimes attend lectures” (39.4%), and “I always rely on Echo360 instead of attending lectures” (11.5%). Students rated the engagement domain highly, and therefore no secondary analyses by learning preference were conducted as part of the current research study.

Engaging Aspects of VPS. By collapsing two of the five-point Likert scale response categories into agree vs. disagree and ordering the items in terms of student agreement, it is easier to evaluate which aspects of the VPS were rated most highly by students.

Interest and Relevance. The survey instrument measured impressions of engagement with four related sub-items regarding increased interest in clinical practice, variety of learning modality, new experiences, and the relevance of the feedback gained by participating in VPS. Table 4 reports the student perceptions of VPS in terms of interest and relevance.

Table 4

The Value of Virtual Patient Simulations in Terms of Interest and Relevance

Statement	Strongly Agree/Agree	
	n	%
They increased my interest in clinical practice.	75	71.5
They added variety to the learning environment.	97	92.4
They provided relevant feedback.	82	78.1
They provided exposure to new experiences.	82	78.8

N = 105

In order of high to low ratings, respondents reported that the VPS added variety to the learning environment (92.4%), provided exposure to new experiences (78.8%), provided relevant feedback (78.1%), or increased interest in clinical practice (71.5%).

Flow. The second sub-component of engagement measured was flow, or "absorption in task." Attributes of flow include unconscious passage of time, enjoyment, and excitement of task. Table 5 displays the results for survey items related to the flow aspect of engagement, designed with Likert items validated by Shiefele and Raabe (2011).

Table 5

The Value of Virtual Patient Simulations in Terms of Flow

Statement	Strongly Agree/Agree	
	n	%
I did not realize how time passed.	70	67.3
I enjoyed working on the tasks.	89	85.6
I was completely absorbed in the activity.	63	60.6
I found the tasks to be quite exciting.	66	63.5

N = 104

Affirmation of the value of VPS in terms of flow was assessed by combining responses for categories *strongly agree* and *agree*. Respondents stated "I enjoyed working on the tasks" (85.6%), "I did not realize how time passed" (67.3%), "I found the tasks to be quite exciting" (63.5%), and "I was completely absorbed in the activities" (60.6%).

Clinical reasoning aspects of VPS activities*.* Student impressions of the clinical reasoning aspect of the VPS were measured by asking students to rate the extent to which they agreed with eight statements (see Table 6). Ranked in order from highest to lowest ratings (combining *agree* and *strongly agree*), a very large majority of respondents indicated that the VPS provided practice with schemes used in inductive reasoning (94.3%). Furthermore, VPS allowed them to gathered evidence from physical examinations to make clinical decisions (91.3%), apply pertinent evidence to reason toward a ballpark diagnosis (90.5%), synthesize evidence to prioritize lab and imaging investigations (88.5%), and increase evidence sorting abilities, (84.8%). Most agreed that VPS integrated medical theory with clinical practice (84.7%). Nearly two thirds (65.7%) agreed that VPS helped them review for exams.

Table 6

Clinical Reasoning Aspects of Virtual Patient Simulation Activities

Statement	Strongly Agree/Agree	
	n	%
They provided practice with schemes and inductive reasoning.	99	94.3
They increased my evidence-sorting abilities.	89	84.8
They helped me review for exams.	69	65.7
They integrated theory with practice.	89	84.7
I made decisions about the sequence of the patient encounter.	92	88.5
I gathered evidence from physical examinations to make clinical decisions.	95	91.3
I synthesized evidence to prioritize lab and imaging investigations.	93	88.5
I applied pertinent evidence at each decision point to reason toward a ball park diagnosis.	95	90.5

N = 105

Socio-collaborative aspects of VPS activities. Participant impressions regarding the socio-collaborative aspects of the VPS were measured with four sub-items related to brainstorming, discussion, and participation. The participants rated this domain highly. Student perceptions are reported in Table 7. Collapsing categories *strongly agree* and *agree* to calculate percentages for each statement, students indicated that “other group members communicated respectfully with me” (94.3%) and “I communicated in a professional manner using respectful language” (91.5%). Responses for the remaining items, in order of highest to lowest ratings are as follows: “I encouraged other members on the team to express their opinions” (88.6%), “group decision brainstorming with fellow students was useful” (86.5%), “team discussion clarified concepts” (85.7%), “working in a small team of three students allowed better participation than working in groups of 10 (84.8%), and “I put in a lot of effort” (83.7%).

Table 7

Socio-Collaborative Aspects of Virtual Patient Simulation Activities

Statement	Strongly Agree/Agree	
	n	%
Brain-storming with fellow medical students was helpful.	92	87.7
Team discussion clarified concepts.	90	85.7
Group decision making was useful.	90	86.5
Working in a small team of 3 allowed better participation than working in a group of 10.	89	84.8
I communicated in a professional manner using respectful language.	96	91.5
I encouraged other members on the team to express their opinions.	93	88.6
Other group members communicated respectfully with me.	99	94.3
I put in a lot of effort.	87	83.7

N = 105

Pre- and Post-Test Results

On December 18, 2013, just after participating in the Exit Survey, 108 students (100%) participated in a randomized control trial. The purpose of this crossover study was to compare the intervention instruction (VPS) to traditional methods (PPT taught by clinical tutor). Comparison groups met in separate classrooms concurrently. Students in each group worked independently to complete a 20-item multiple choice pre-test, followed by group instruction with a 20 minute case, followed by a 20-item multiple choice post-test. This process was repeated twice: reported as sessions I and II. Traditional instruction was delivered by the same clinical tutor for both groups: a professor / physician internist DO with 7 years of clinical experience and five years of higher education teaching experience.

Student allocation, randomized control trial. The first year coordinator randomly assigned students into two groups: Galen and Hippocrates. These sub-groups received instruction for 20 minute segments in two separate rooms for a total of two repeated sessions in a crossover design. (See Figure 34).

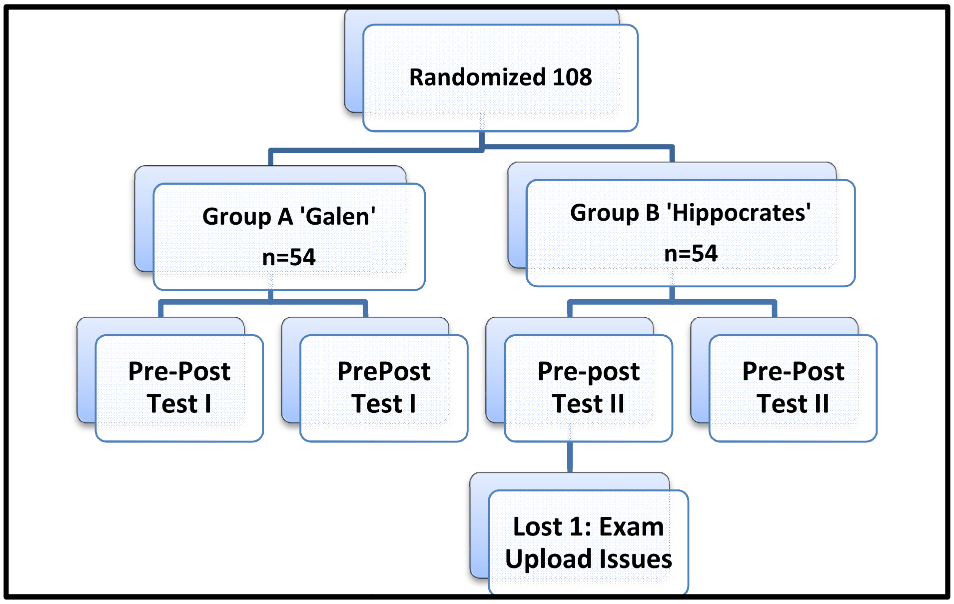


Figure 34. Flow diagram of student allocation, randomized control trial.

During the first session, Galen received the intervention (VPS) instruction first during the first case regarding non-serious palpitations, entitled “A Night on Call in the Telemetry Unit”. Meanwhile, Hippocrates received instruction with the same case via PPT. In the second session, Galen received the intervention instruction via PPT, during the first second case regarding serious palpitations “It’s Everywhere You Go,” while Hippocrates received instruction on the same case via VPS. The first case included material that was foundational to the second case.

Hypothesis 1c states: [VPS are effective for improving clinical decision-making.] Data in Table 8 affirm hypothesis 1c. They suggest that no matter the mode of instruction, or order of presentation, all variations of the sequence: pre-test–> instruction-> post-test resulted in significant gains.

Table 8

Means and Standard Deviation Scores by Group, Mode and Session

Mode (Session*)	Group	Pre-Test M % (*SD*)	Post-Test M % (*SD*)	Gain M %	*P*
PPT (1)	Hippocrates	44.49 (13.44)	57.90 (10.17)	13.41	.002
PPT (2)	Galen	62.59 (10.31)	78.33 (10.64)	15.74	.001
VPS (1)	Galen	45.42 (13.34)	52.73 (12.75)	7.31	.000
VPS (2)	Hippocrates	67.36 (13.11)	79.15 (9.49)	11.79	.016

*Session

Research hypothesis 1 D states: [VPS are more effective than traditional case PPT's for teaching clinical reasoning skills as measured by a significant difference in mean gain between pre-and post-tests.] Prior to discussing the outcome, it is necessary to consider interactions. Table 8 presents the outcome of the crossover trial with two comparison groups. A multivariate analysis of variance revealed a significant three-way interaction (group x mode x session), *F*=9.34 (1,105), p=0.003 $\eta^{2} =$ .082. Specifically, the degree of change in test scores pre-to-post (change score, or 'gain') differed, depending on both the mode of instruction (VPS vs. PPT) and the order in which this instruction was provided, (VPS first or PPT first). Table 8 provides the mean and standard deviations of test scores for each condition. PPT instruction resulted in significantly higher learning gains (14.59%), SD=1.16, than VPS (9.53%) (SD= 1.19), *p*=.003, η^2 =.08.

Effect size and power. According to Plano-Clark and Creswell (2009), "the effect size is a means for identifying the practical strength of the conclusions about group differences or relationship among variables in a quantitative study." (p.221). In the design of this crossover, there were four variables: group, modality of instruction, order of mode of instruction, and session. Due to these multiple variables, the MANOVA indicates that the effect from the three-way interaction of group x mode (VPS and PPT) and session was $\eta^{2} =$ .082, whereas the effect of the mode of instruction was .080. Cohen (1988) and Olejnik & Angelina (2000) suggested that η^2 values equal to or exceeding .01, .06, and .14 are considered to be small, medium and large effect sizes, respectively, when proportion of variance accounted for is used as a measure of effect size for a within-subjects design. Both of these effect sizes reflect a medium effect size according to Cohen's criteria (Olejnik & Angelina, 2000). The statistical power was sufficient at .857, exceeding minimum of .8 required (Park, 2010; Greene, 2000).

As reported in Table 9, there was also a significant two-way interaction (group x session F= 4.3 (1,105), (p=0.041), η^2 = .039, a small effect.

Table 9

Means and Standard Deviation Scores by Group and Session

Group (Mode)	Session I Gain M %)	*SD*	Session II Gain M%	*SD*
Galen (VPS-1st, PPT 2nd)	7.31	10.89	15.74	10.92
Hippocrates (PPT-1st, VPS 2nd)	13.41	13.44	11.79	13.10
Total	44.96	13.34	64.95	11.96

p<.05 df = 105. Galen n=54, Hippocrates n=53. Total N=107

Figure 35 reflects the data in Table 9, plotting differences in learning gain between sessions and groups, and between pre- and post-test. During the first session, the Hippocrates group, receiving (control) traditional PPT instruction for 20 minutes scored a higher mean greater learning gain than the Galen Group, receiving VPS instruction. During the second session, while both groups scored a higher pre-test score. The Hippocrates (intervention) group scored a higher initial mean at pre-test than Galen (control). At post-test, Session II, the two groups achieved nearly the same culminating score, within one point (.9%) indicating that the end performance score was similar between groups.

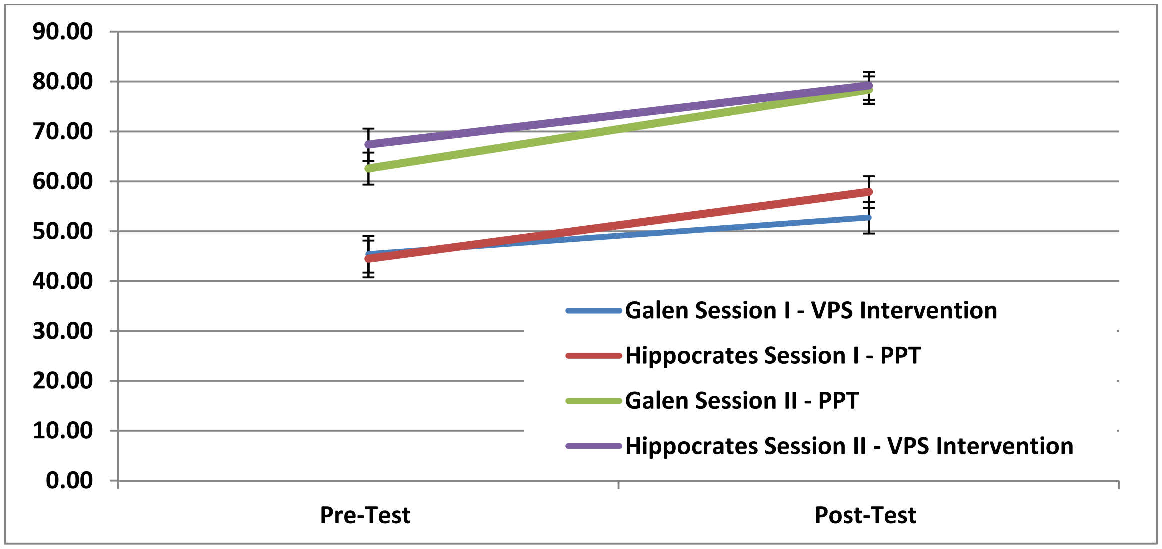


Figure 35. Pre-and post-test results: Learning outcome by mode of instruction, sessions I & II.

Equality of distribution among pre- and post-tests. A one-sample Kolmogrov-Smirnov test (K-S) was calculated to ensure that the distributions were equal among observations. Within the data set, there were a few outliers, but in general, the distributions did not differ from normal parameters; results were non-significant ($p>.05$). Distributions of the four assessments and item statistics for the pre- and post-tests are provided in Appendix Q.

Section 2: Qualitative Data

This section presents findings from the qualitative measures: survey open answer responses, transcribed student discussions, session photographs, and tutor feedback.

Exit Survey Open Responses

As reported in Figure 36, student participants provided 55 open responses to the last item of the electronic survey: “How may we improve these [VPS] activities?” Student statements were downloaded from SurveyMonkey, parsed into statements, and open coded into eight themes. These themes are listed in Figure 38 as follows: 1) General comments, 2) Activity format, 3) Anytime practice, 4) Case Content, 5) Case Format, 6) Clarity, 7) Quantity of Text, and 8) Time constraints.

Exit Survey Open Comments by Theme and Frequency			
Theme	n	Frequency/ Code	Sample Student Comments
General Comment	8	4 no improvements to recommend 1 sims were good activities 1 refining the sims 1 not sure they are effective 1 facilitator discussions	**Facilitator discussions** *"Facilitator discussions are way better (but it depends a lot on which facilitator)."*
Activity Format	14	6 triads should meet in separate rooms 5 when to schedule the sims 1 add complexity to the activity worksheet 1 would've rather picked my group 1 students should prepare prior to the simulation	**Triads should meet in separate rooms.** *"Videos are a nice idea but when several groups are together in the same room we couldn't really watch the videos or if we did the sound would overlap with each other so a lot of times we didn't even bother to watch the videos even though they looked informative and interesting."*
Desire for Individual Study	4	3 bank of simulation situations 1 independent study	**Bank of Simulation Situations.** *"Eventually, if you're able to develop a bank of simulation situations, I think that would be really helpful. I would practice them in my own time."*
Case Content	6	2 review material too extensive 1 increase the complexity of the cases 1 match case content to large group lesson 1 tasks too detailed 1 diagnosis feedback	**Review Material Side Loops** *"There were so many asides when all I wanted to do was assess and treat my patient. I didn't want to learn about each aspect of care as I made decisions. I wanted to assess, think quickly, treat, and then find out what happened—kind of like a video game."* **Diagnosis Feedback** *"Go through the scenario and then provide relative information on why certain diagnoses are correct. More pertinent negatives would also be helpful. In other words, I want to know why certain diagnoses are wrong."*
Case Format	6	2 embedded videos 2 patient chart 1 length of case 1 linear flow of case	**Patient Chart** *"Have the option to go back and look at the HPI * and previous screens in case we forgot what the age and specific symptoms of the patient was."*
Clarity	9	3 feedback 1 answer choices 1 questions 1 spelling 1 grammar	**Feedback** *"Sometimes it would say when I answered correctly and other times it didn't. It was most helpful when I knew if I was right in my reasoning."*
Quantity of Text	4	4 reduce the text	**Reduce the Text** *"Some pages of the VPS had a lot of text. Since we were given a time limit to get as far as we could in the case, we found that we would briefly skim or just completely skip these long passages."*
Time Constraints	10	8 20 minutes insufficient 2 timer	**Time Constraints** "*I would like more time for each activity in order to be able to absorb the materials more completely."*

Figure 36. Exit survey open comments by theme and frequency.
*History of the Present Illness (HPI)

Tutor Feedback Results

In the fall of 2013, six tutors provided a total of 28 feedback forms: practice session #1 (11 feedback forms), session #2 (7 forms) session #3 (6 forms) and session 4 (4 forms). The tutor feedback forms solicited commentary in open answer format. Their feedback was divided into “feedback on the learning experience” (Fig. 37) and “feedback on the VPS modality” (Fig. 38).

Tutor feedback on the quality of the learning experience. The data in Figure 37 indicate that tutors felt that VPS were a useful learning activity. The students were absorbed in the task–an indication of flow, and they exhibited participatory discussion.

A Priori Category	Theme	Code/ Frequency of Code	Example Tutor Feedback
Clinical Decision Making	Useful learning activity	Good learning activity (4)	*“A good learning experience with interesting and helpful information.”*
		Case content (2)	*“Students were not familiar with CAGE questions.”* *“Musculoskeletal vs. neurology tough.”*
Engagement	Flow	Flow/Involvement (1)	*“Involved and immersed.”*
		Focus on activity (2)	*“Good attention and flow.”*
		Engagement (3)	*“All: Good immersion. Discussions good depth. Very engaged.”*
		Enthusiastic outburst (2)	*“Some cheering noted and arm waving.”*
		Wish to continue working (1)	*“During the remainder of the lesson, some students were sneaking back onto DS to finish the case.”*
Collaboration	Participatory Discussion	Collaboration from the tutor’s perspective (2)	*“Team good cooperation and discussion.”* *“One group less good discussion and interactive participation but seems at some decision points picked up interactions.”*

Figure 37. Tutor feedback on the quality of the learning experience

As presented in Figure 37, the frequency of comments is presented in parentheses. Tutors made several positive comments about the learning activity, with comments such as “Good immersion,” “Discussions good depth,” and “Very engaged.” They also pointed out content areas that were challenging for students, such as *“Musculoskeletal vs. neurology tough.”* Some noted that the discussions were good. Their feedback indicated that the activity held the attention of the majority of the students. In a few cases, tutors mentioned that one student or one group of three was not as keenly involved. Some enthusiasm was noted. For example, at times, students were cheering when they chose correct answers. Some teams did not wish to end the activity after 20 minutes. One tutor noted that following PPT case sessions, some students returned to the simulation case. Some tutors mentioned that the students were cooperating well.

Tutor feedback on the VPS modality. Qualitative data from tutors about the VPS activity (Figure 38) shed light on a few issues with the VPS activities in five main themes: quantity and quality of screen text, technical glitches, classroom environment, time allocation, and tutor role. Quotations from Tutor Feedback forms are provided in Figure 38. Tutors indicated that were periods of silence while students read the simulation pages instead of discussing—lessons were detailed and focused on clinical reasoning. In general there were not many technical glitches, but one or two times, students had trouble logging on. It grew loud when different student teams were in the same room and trying to listen to videos within the simulations. During one of the sessions, a tutor commented that the students were having better luck with computers (compared to the prior academic year). During VPS session four, there was a brief internet outage. Several tutors mentioned that the cases could not be completed in 20 minutes. During the first session, students were slower because they were not familiar with the simulation tasks or user interface. Although the tutors were available, students did not request assistance.

***A Priori* Domain**	**Category**	**Code**	**Example Tutor Feedback**
P S A ct	**Quantity and quality of screen text**	[Screen] Text	*“Excessive verbiage in the text. Too much to read.”*
		Silence while reading	*“Silence while reading.”*
	Technical Glitches	Logging on	*“One group had trouble logging onto site.”* *“Suggestion: special link for DS to speed access.”*
		No technical glitches	*“Better luck with computers.”*
		Technical glitch	*“Screens froze with 2-3 slides left.” [internet outage]*
	Classroom Environment	Several teams in one room/ Video	“*A little difficult for the students when the videos were playing at the same time. Cacophony. Hard for them to moderate the video.”*
	Time allocated for activity	Insufficient time to complete case	“*Can’t be done in 20 minutes if the group needs to discuss it.”*
		Tutor review of task	“*[Students are] slower as not familiar with the process.”*
	Tutor as “guide on the side” during VPS	Questions to facilitators	*“Clarification asked by one team – re: determining meaning of choices.”*

Figure 38: Tutor Feedback on the VPS Modality

Session Classroom Photographs Results

In order to compare levels of engagement and collaboration among VPS and traditional case practice, I took 292 photographs during four case sessions. Table 10 lists the numbers of photographs taken for each of the four practice sessions. The data set included a proportionally greater number of VPS photographs (165) because the small group tutors allowed the students to continue with the VPS beyond the 20 minute time limit. Transition time photographs reflect activities that were happening in between the Decision Simulation (VPS) and the traditional instruction led by the tutor via PowerPoint, such as a debrief of the simulation, waiting while other teams finished the task or the Competency Task.

Table 10

An Inventory of Classroom Photographs by Modality of Instruction

	VPS	Transition	Traditional	Total
Session 1 10.7.13	49	2	30	81
Session 2 10.11.13	45	10	30	85
Session 3 11.8.13	41	9	10	60
Session 4 11.15.13	30	13	23	66
Totals	165	34	93	292

Photographs by level of engagement and modality of instruction.

Figure 39 provides an overview of the entire data set of 292 categorized by code and theme, and presented in the researcher's matrix of engagement levels. The photographic data in Figure 39 indicate that in comparison to traditional instruction, VPS activities did foster a high level of engagement, defined as rapt concentration, leaning in, focusing on task and interactive behaviors. Traditional instruction did evince more passive listening and lethargy, fatigue or low engagement as defined as leaning away or crossing arms in a closed pose.

Level	Level of Engagement	Category/ Code	VPS	Transition	Traditional
		Total Photographs taken	Photo n=165	Photo n=34	Photo n=93
High Engagement	**Very High**	**Highly Engaged- at least one student** Pleased expression Rapt concentration	37	4	1
	High	**Leaning In-all students**	51		
	High	**Focused on Task – all students** Focused on simulation Focused on PPT	64		22
	High	**Interactive-at least one student** Gesturing to illustrate joint Pointing to the simulation on laptop Discussing with tutor Taking notes Discussing with peers	42	6	11
Medium	**Medium**	**Transition Activities*** Some teams finishing the simulation Completing Competency Task Waiting while others finish VPS Discussing with tutor		34	
	Medium	**Passive Pose- all students**			25
ow	**Low**	**Low Enthusiasm but Focused on Task -at least one student** Head in hand leaning down Lethargic demeanor	13		22
	Low	**Low Enthusiasm-Less Focused on Task** Not paying attention to PPT Difficult to see VPS screen Leaning away or reclining back	5		13
	Very Low	**Reserved – at least one student** Sitting with arms crossed.			21

Figure 39. Classroom photographs by level of engagement and modality of instruction.
*There was a period of transition between VPS and traditional small group instruction.
Student N=107. Photo N=292. Some photographs were cross-coded to more than one category.

Time sequence analysis. Another method of data analysis suggested by Pink (2007) was to select a time sequence and describe a narrative of a specific case of activity through a related collection of photographs. In Figure 40, three male students complete a VPS. In the first photo, the students display “rapt concentration.” The second photo reveals a high level of focus, but the students are not leaning in quite as far.

Figure 40: Time lapse sequence of a VPS session.

The third photograph display one student with a pleased expression—as the team considers the diagnosis. Notice the Diagnostic Competency Task form on the keyboard. In the final photograph of this sequence, the students turn their heads toward one another, an indication of peer-collaborative discussion.

Researcher Observations and Memos Results

During the four VPS practice sessions, I observed the VPS sessions via remote camera in real time as they transpired in six small group classrooms. During these sessions, I hand wrote notes onto a paper observation form. After each session, I typed an analysis memo about the experience. These researcher documents were open coded (inductively) in HyperResearch 3.5.2. From HyperResearch, I printed output tables listing the codes and associated data sources and moved them into Excel. The codes were grouped into spreadsheets for each of the domains associated with this study: clinical decision making, collaboration, and engagement.

The utility of VPS for clinical reasoning: Researcher's perspective. The body of researcher observation notes and memos highlighted eight facets of the clinical decision making process, providing evidence that the VPS exercises supported deliberate practice with clinical decision making through eight facets of the patient interview: history, order of investigation, clinical presentation, anatomy and osteopathy, resolving muddy points, diagnosis, and clinical pearls. Through VPS, students decide how much patient history to obtain. For example, in the very first patient case, students read the first page of the clinical presentation and mistakenly thought this was the patient history. Later they discovered there was much more to learn about the patient. Due to the branching nature of VPS, students decide the priority of the investigations, instead of being guided through a step-wise process.

Students asked each other excellent questions about the patient data. I witnessed rich discussion at specific decision points along the scheme pathways. For example, for scheme "limb pain", students discussed a decision between "articular and "non-articular" pain

> S1: What do you think? Which is it going to be? It's quite tender and it hurts.
> S2: I think it's articular. Because, hold on a sec.
> S3: Pain with and without.
> S2: Referred musculoskeletal pain likely to be ….neck…so…
> S3: …is the actual joint itself.
> S2: We are talking about articular vs. non-articular [pain]. The pain increases with movement of the shoulder joint.
> S1: Is it a rotator cuff problem? Rotator cuff would be articular.

During the limb pain and back pain cases, the students discussed the anatomy of joints. During these discussions, they referred to medical jargon and anatomical terms such as abduction and flexion learned from their osteopathic principles and anatomy courses, sometimes stretching their limbs to show extension and flexion or to check joint rotation. Since students were learning how to complete a patient examination in a separate, concurrent Medical Skills course, the VPS provided continuity by providing practice regarding focused physical examinations. Figure 41 presents the codes and sample extracted quotes from researcher observations and memos.

A Priori Category	Code	Example Researcher Notes
Clinical Decision Making	Patient history	*"At one point students were not sure they needed to collect more history. This represents novice thinking, as one of the faculty pointed out."*
	Order of investigations	*"I noticed when looking at the transcription that the Decision Simulation requires the students figure out what part of the patient encounter to do first, second third."*
	Sorting evidence	*"Students interrogate the patient data, questioning each other: 'What evidence do we have for ….?'"*
	Clinical presentation (CP) scheme	*"Students discuss a decision branch point on the scheme [regarding shoulder pain]: 'We are talking about articular vs. non-articular [pain]. The pain increases with movement of the shoulder joint.'"*
	Anatomy and OPP	*"The student team that I am observing holds a detailed discussion about joints and anatomy. Through this discussion, they review of osteopathic principles and practice (OPP) and medical skills."*
	Muddy point	*"Is a muddy point really a bad thing? Even if students are confused, even frustrated, and debate a long time, doesn't this mean they are engaged?"*
	Develop theory or diagnosis	*"While the students show struggle and spend more than ten extra minutes running to the end of the session, they show great interest in this case, and in obtaining the correct diagnosis."*
	Clinical pearls	*"Three female students work through a case. There is very rich clinical discussion…They don't need to do this, because they have completed the competency task, but they read through the section called 'clinical pearls' and discuss them."*

Figure 41. Researcher notes and memos by domain: Clinical decision-making.

During the VPS, students encountered unresolved questions or gray areas (muddy points). For this reason, I designed each simulation session to be followed by tutor-led debrief. In my observation records, I realized that it might be helpful to track the "muddy points" raised by students during the VPS, and document them as "case notes" for the clinical tutors (for unpacking during the VPS session debriefs next year). Following is an example a tutor clearing up a muddy point from the VPS case regarding seizures on 11.8.13.

Student: *"Are seizures painful?"*

Tutor: *No. They're not. I mean the consequences can be painful if you fall down and hit your head. Obviously. Or break your leg or something. But an epileptic event is by and large not painful while it's occurring. Because why? The brain is a receptor of pain, but* *not a producer of pain. I can receive pain from an incident like stubbing your finger or something. And it can record that, but it doesn't generate pain. So that's why the surgeon can put probes into the brain, and the patient can be awake, they drill a hole, use local anesthesia. Put a probe into the brain to treat Parkinson's disease or gather recordings for epilepsy, but you don't feel it. So epilepsy itself is not. If pain is the initial symptom, then be very suspicious of a diagnosis of epilepsy. Any other questions?*

During these simulation episodes, the development of the diagnosis was important to the students. But this was an inductive process, and the VPS required the students to reason toward a diagnosis, not defend an *a priori* differential. Not every VPS contained a section entitled "clinical pearls", but the VPS associated with "seizure" contained one. Even though the students had completed the primary diagnosis task, they reviewed the clinical pearls in the lesson.

Disconfirming evidence: Clinical reasoning. Disconfirming evidence regarding the effectiveness of the VPS for supporting clinical reasoning revolves around the issue of confusion. When novice medical students guided their own discovery through a case, in every case observed in detail they were not completely clear about each aspect of the case, nor what to do in each situation.

The utility of VPS for fostering collaboration: Researcher's perspective. Analysis of the researcher observations and memos indicates that VPS foster collaboration. (See Figure 42). Research observation notes and memos provided concrete examples of collaboration in four facets: professional tone, team spirit, peer discussion, and participation.

1. Professional tone: During the VPS observed, for the vast majority, the students exhibited a professional tone, practicing peripheral (sheltered) simulated participation in their future role as physicians.
2. Participation: In all of the student conversations I observed and transcribed fully, each member of the student triad team contributed effectively.
3. Peer discussion: During the four sessions I observed and transcribed from beginning to end, there was rich peer discussion. During one session, students were even discussing while concurrently watching a short video clip regarding vertigo.
4. Team spirit: Students often expressed team spirit during the VPS. One team remarked, "good job, guys!" in reference to the reward video.

A Priori Category	Code	Example Researcher Notes
Collaboration	Professional tone	*"The students discuss using a professional tone, assuming the personae of physicians."*
	Participation equity	*"All were participating effectively. No student dominated the conversation."*
	Peer discussion	*"The video within the session sparks discussion. The students are discussing the video all the way through [it]."*
	Team spirit	*"The students are watching their reward video: "Good job, guys! It's telling us we did good. That was exciting."*

Figure 42. Researcher notes and memos by domain: Collaboration.

The utility of VPS for fostering engagement: Researcher's perspective. Researcher observation notes and memos indicate that VPS foster engagement. These data sources rendered insights regarding seven aspects of engagement: anxiety, focus, humor, interest, enthusiasm regarding the score, gratitude to the case author, and wish to continue. The results of this analysis indicate that in general, the VPS foster cognitive engagement. Figure 43 provides examples of data for each of eight codes.

Anxiety (new task apprehension). Prior to the first practice session, one student expressed apprehension about the exercise. This was the first time she had ever encountered a Decision Simulation, and was unfamiliar with the user interface. She didn't know how to pace herself. In my notes, I considered a possible future training topic: How should physician professionals express their worries to each other, in order not to appear over-anxious? While cognizant of their time limit of 20 minutes, these students managed through the case very well, despite initial concerns.

A Priori Domain	Code	Example Researcher Notation Regarding VPS Activities
Engagement	Anxiety	*[First case, first five minutes]. "A student expresses that she feels anxious to complete this case. Using micro-analysis to explore why she is so anxious, she is saying "because we are video-recorded, because I don't know what to do about the competency task, because it's difficult, because of the time pressure, because there is no professor here."*
	Note-Taking	*"Very few students were observed taking notes during VPS."*
	Focus	*"In the small group room I observed, the students were fully engaged and at one point, even stopped looking at the game [VPS] and sat in a triangle discussing the case."*
	Interest	*"One colleague observing from the control room said the students were "pimping" each other – this means challenging each other with questions about the case."*
	Humor	*[In reviewing action on monitors from the control room]."There was laughter in several rooms."*
	Enthusiasm about score	*"Students discuss their score at the end of the case (out of 100 points) "85%. Not bad!"*
	Gratitude to professor	*"At the end of the case, the students thank the absent professor who wrote the case: 'Thanks, Dr. C!'"*
	Wish to continue	*"Students asked to stop at 20 minutes requested more time to do the case."*

Figure 43. Researcher notes and memos by domain: Engagement.

Focus. Students displayed great attention and focus on each session I observed. In one session, team members were so drawn into the case that they forgot time and task, sitting in a triangle discussing case details.

Interest. Students revealed that they felt the topics were relevant by working above and beyond arriving at diagnosis: they quizzed each other through the case objectives, defined terms for each other, and tested each other's knowledge regarding key concepts. In one of the four sessions I observed fully, one of the participants was quite reserved and aloof at the beginning. Gradually she was drawn into the very epicenter of the discussion.

Humor, enthusiasm, gratitude. I noted several instances of student laughter and humor during the VPS sessions in real time. This observation was corroborated by other observer colleagues. On more than one occasion, I noted that students expressed interested in their scores, and enthusiasm upon receiving a high score. At the close of one session, students politely thanked the professor who wrote the case (though he was not present there in person).

Wish to continue the simulation beyond the time allocated. For the first session, the tutors were instructed to end VPS after 20 minutes, and therefore they called time and ended the VPS at this point. The students in the triad I observed were reluctant to end the session, because they requested more time to complete the case. Subsequently, the small group tutors requested that there be the option to continue longer with the simulation cases. Students were not graded on this activity and were not required to continue, but in every case upon completing the competency task, students continued with the case if they had not completed it in 20 minutes to review topics such as treatments and clinical pearls.

Researcher observations about implementing the VPS activity. One of the main functions of the observation records was to track and verify that the sessions were implemented with fidelity, meaning according to guidelines set by the study. Figure 44 documents the ways in which the implementation guidelines for each session were met in general terms. The notes column mentions any caveats or minor implementation flaws.

Aspect	Implementation per plan sessions 1-4				Notes
	1	2	3	4	
Tutors were briefed prior to the lesson	✓	✓	✓	✓	During the first session, the tutor I observed answered questions about the research study. It was emphasized very clearly that students were being recorded.
Student triad formations are per design.	✓	✓	✓	✓	
Students accessed the cases online with no problems.					
The competency task was implemented properly.	✓	✓	✓	✓	During the third session, the tutor I observed handed out the competency task two minutes late to the triad I observed. The students left it on the table as they exited the room instead of putting it in the envelope. Later they collected it and placed in the envelope.
There were no major technical glitches during the VPS session	✓	✓	✓	✓	During the fourth session, an internet failure obliged students to re-log on for some of the 33 groups. Two minutes lost were added to their session. During the final session, the video recording system failed.

Figure 44. Implementation report.

In order to assure fidelity of the research and activity implementation plan, I met with the tutors for an hour prior to each of the four sessions to explain the sequence and competency task. At these sessions, VPS case authors were present, and walked the tutors through each case. In reviewing the observation notes from all four practice sessions, the sessions were implemented with fidelity with minor aberrations that did not affect the validity–quite normal in the midst of concurrent activity in six high-tech interactive classroom activities.

Transcriptions of Student Discussions Results

Comparing discussion topics among selected VPS and traditional small group sessions*.* Figure 45 lists major topics of student discussion during VPS and traditional, tutor-led instruction for the four VPS and four traditional instruction discussions randomly selected for transcription.

***A Priori* Category**	**Theme**	**Discussion Code**	**Frequency of Code over 4 discussions**	
			VPS	Traditional
Clinical Decision Making	Chief Complaint/	Clinical Presentation (CP) Scheme	11	15
		Prioritize steps of patient encounter	3	0
	History	Patient History	7	12
	Patient Exam	Clinical Pearls Red Flags Patient Exam	4	10
		Anatomy/Physiology/OPP*	2*	13
	Investigations & Procedures	Analyze Patient Data	8	
		Lab and Image Choice	21	8
		Biochemistry/ Define a term or concept	0	10
		Interpret lab and imaging	1	4
		Cost of procedures	3	0
	Peer Debate	Deep discussion Debate	8	1
		Muddy point – (unresolved)	4	2
		Frustration: decision making	3	0
	Diagnosis	Statement of [ballpark] diagnosis	7	2
	Treatments	Treatments	3	8

Figure 45. Student clinical decision-making during VPS and PPT cases by theme.
*OPP = Osteopathic Principles and Practice

Both modalities of instruction fostered clinical reasoning, but the discussion was concentrated in different aspects of the patient case depending upon the mode of instruction. During VPS, students spent time discussing CP scheme decision points, patient data, lab and image choices, case decisions, and the diagnosis. Since the VPS were not linear cases, the students were required to select the order of investigations. A matrix presenting examples of student dialog, and their alignment with discussion topics to AOA competencies is provided in Appendix P.

Disconfirming evidence that VPS foster clinical reasoning. Students expressed a measure of confusion when they encountered imaging or lab choices that were challenging for them (especially given the 20-minute time limit). However, in each session observed, students pooled knowledge to reason through the evidence to arrive at consensus decisions. There were opportunities during a subsequent debrief with their clinical tutors to clarify muddy points. In addition to the evidence regarding confusion and muddy points, the code "silence while reading" appeared nine times during analysis of the student VPS discussions. Together with other evidence collected through the exit survey and tutor feedback indicates that there was sometimes too much text, causing dissonant struggle while students worked through the case.

Tutor's role during VPS sessions. Transcriptions revealed that during the VPS activities, tutors provided positive reinforcement, clarified incorrect information, and answered questions. Since the tutors provided time for students to raise and resolve outstanding questions, students did not need to struggle to co-construct knowledge or encounter confusion as much during tutor-guided case practice. For example, students did not have to select the order of investigation during the PPT linear case.

Tutor's role during traditional small group. The data revealed that these sessions concentrated more intensively on the clinical presentation scheme, patient history, patient exam, and interpretation of lab and imaging. The following codes indicate the scope of tutor activities:

1. Answering student questions (20+ instances)
2. Explaining and clarifying (12)
3. Asking students questions (12)

4. Discussing the case PowerPoint slides (12)
5. Sharing a clinical experience or war story (6)
6. Facilitating discussion as guide on the side (6)
7. Explaining the tasks for the activity (5)
8. Offering positive reinforcement (4)
9. Managing transition time between VPS and traditional instruction (4)
10. Using the white board to diagram the CP scheme (2)
11. Role playing as patient (1)

Typically, tutors cleared up muddy points through dialectics (the process of questions and answers). Being clinicians, tutors were able to explain pearls of practice regarding treatments to students, who raised many questions regarding medication dosages and alternative therapies.

Variability among tutor-led sessions. While case PowerPoints (PPT) were standard for all small groups, transcriptions of sessions revealed variability among the style of discussion facilitation. During the first session (a limb pain case), the first tutor posed as a patient, and asked the students to role play the physician and lead the patient interview. This style rendered an equal distribution of discussion "air time" between students and tutor. During the second session (a case about back pain), a second tutor provided clinical pearls such as treatment therapies for orthopedics among elderly patients, and answered novice questions such as whether the physician should conduct the seven parts of the history of the patient illness for each complaint if the patient presents with more than one complaint. During the third session (a case regarding seizure) the tutor asked and answered many questions regarding the basic science of brain neurology, and allowed students time to ask dozens of questions. Transcription of the fourth session revealed that the tutor focused on the clinical presentation "seizure." In this session, the tutor played the role of "guide on the side". He asked the students to take charge of the discussion, explaining that he would jump in if there were issues to clarify. During this lesson, the tutor also asked students to use the white board to construct a diagram of the scheme flowchart from memory. This method generated avid discussion among student peers.

Section 3: Results Summary

During this study, data were collected from seven core measures. Figure 46 provides a summary of results for each core measure. Competency Task data revealed that student teams arrived at the accurate diagnosis over four case sessions with a mean rate of 92%. Exit survey results indicated that students perceived VPS to foster clinical reasoning, collaboration and engagement. Students provided ample feedback via the exit survey regarding ways to improve the VPS in eight themes. Pre-and post-test results suggest that PPT was more effective than VPS, but students made significant learning gains in both modalities, and there was a statistically significant three-way interaction between group, mode of instruction, and session that tempers the first finding. Tutors provided valuable feedback indicating that they felt the VPS activities were useful in three learning domains: clinical reasoning, collaboration, engagement. Tutors also generated constructive feedback regarding ways to improve VPS mode of instruction. Specifically, they recommended reducing screen text and increasing the time allocation beyond 20 minutes. Session photos suggested that students were more engaged and focused during VPS activities than traditional case instruction. Observer memos and notes suggest that students held rich discussions about clinical cases but displayed constructive and dissonant struggle with difficult concepts. Finally, analysis of student dialog confirmed that students held rich discussions in all the different phases of the patient interview. There was a slightly different emphasis in clinical topics among VPS and traditional case sessions.

Measure	Key Findings, Main Study			
1. Diagnostic Competency Task	**Clinical Reasoning:** Student teams arrived at the accurate diagnosis over four case sessions with a mean rate of 92%.			
2a. Exit Survey	**Clinical Reasoning** 84.7-67.5% of student participants agreed that VPS supported aspects of clinical decision making	**Collaboration** 83.7-94.3% of student participants indicated that VPS supported peer collaboration.	**Engagement** 71.5-92.4% of student participants agreed that VPS were interesting and relevant. 67.3-85.6% experienced flow.	
2b. Exit survey Open Responses	**VPS Design: "How can we Improve these activities?"** Students returned 55 comments in eight themes: 1) General comments: 5 positive, three constructive, 2) Activity format, 3) Desire for independent study, 4) Case Content, 5) Case Format, 6) Clarity, 7) Quantity of Text, and 8) Time constraints.			
3. Pre-and Post-Test	**Clinical Reasoning** Significant findings include: • Case instruction via PPT resulted in greater learning gains than VPS $p=.003$, $\eta^2=.080$ • Case instruction via VPS resulted in learning gains $p<.001$. • Group x mode x session, $p=.003$, $\eta^2 = .082$ • Group x Session I (7.3%), Session II (11.8%) $p=0.041$, $\eta^2 = .039$			
4. Tutor Feedback	**Clinical Reasoning** VPS are useful as a learning activity. Some content areas were challenging.	**Collaboration** Students cooperated during discussions.	**Engagement** Students were in the flow, but separate teams to reduce noise.	**VPS Design** Reduce screen text. Increase time allocation > 20 minutes.
5. Session Classroom Photographs	**Engagement** • Analysis of 292 photographs indicated that most students were focused during VPS activities. • Students seem more engaged during VPS activities than traditional instruction.		**Collaboration** Photographs confirm that students engaged in collaborative discussions during VPS.	
6. Researcher Observations and Memos	**Clinical Reasoning** Students held rich discussions about clinical cases but displayed constructive and dissonant struggle with various concepts.	**Collaboration** Students exhibited collaboration.	**Engagement** Aside from minor initial anxiety, students were engaged.	**VPS** VPS practice sessions were implemented with fidelity.
7. Transcriptions of Student Discussions	**Clinical Reasoning** • Students worked through all phases of a patient encounter during VPS. • Tutor-led sessions emphasized different aspects of the patient encounter, such as biochemistry, procedures, image interpretation, and treatments.			

Figure 46. Results summary.

The findings in Figure 46 are categorized by the three a priori learning domains of the study, as well as the design domain, anticipating the triangulation for Chapter 6.

Chapter 6 - Discussion

Introduction

Chapter 5 reports the results of each data source. In this chapter, I will triangulate among data sources and discuss findings by research question. Researcher Robert Stake (2005) explains data triangulation as a method used by researchers “to increase credence in interpretations, to demonstrate the commonality of assertions” (p. 112). I increased the accuracy and reliability of my findings by confirming each assertion using two to four different data sources.

Research Question 1: Clinical Decision Making

Research question 1 inquires: *[For OMSI students, to what extent does deliberate practice with virtual patient simulation improve skills in clinical decision-making?]* To answer this question, three quantitative data sources were triangulated to test four hypotheses: 1) Diagnostic Competency Task, 2) Exit Survey, and 3) Pre- and post- test results (Figure 47).

<table>
<tr><th colspan="6">Hypotheses & Key Evidence</th><th>Confirmed</th></tr>
<tr><td colspan="6">A. Student teams will demonstrate competency in clinical decision-making as measured by accurately completing 4 diagnosis performance tasks [after completing VPS] with a mean greater than 70%. (Source: Competency Task)</td><td>✓
92% accuracy</td></tr>
<tr><td colspan="6">B. Students agree [or strongly agree] that VPS are valuable for practicing clinical decision making. (Source: Exit Survey)

1. Provided practice with schemes and inductive reasoning (94.3%)
2. Gathering evidence from physical examinations (91.3%)
3. Applying evidence to reason toward a ball park diagnosis (90.5)
4. Synthesizing evidence to prioritize lab and imaging investigations (88.5%)
5. Sequencing the patient encounter (88.5%)
6. Sorting evidence (84.8)
7. Integrating theory with practice (84.7%)
8. Reviewing for exams (65.7%)</td><td>✓</td></tr>
<tr><td colspan="6">C. VPS improve clinical decision-making skills, as demonstrated by a significant learning gain, pre- to post-test. (Source: Pre- and Post-Test)</td><td rowspan="3">✓</td></tr>
<tr><td>Mode</td><td>Session</td><td>Mean Gain</td><td>Sig.</td><td>Session</td><td>Mean Gain</td></tr>
<tr><td>VPS</td><td>I</td><td>7.3%</td><td>.000</td><td>II</td><td>11.8%</td></tr>
<tr><td colspan="6">D. VPS are more effective than traditional instruction with PPT’s for improving clinical decision making. (Source: Pre- and Post-Test)</td><td rowspan="4">No</td></tr>
<tr><td>Mode</td><td>Session</td><td>Mean Gain</td><td>Sig.</td><td>Session</td><td>Mean Gain</td></tr>
<tr><td>PPT</td><td>I</td><td>13.4</td><td>.002</td><td>II</td><td>15.7</td></tr>
<tr><td>VPS</td><td>I</td><td>7.3%</td><td>.000</td><td>II</td><td>11.8%</td></tr>
</table>

Figure 47. Results triangulation for research question 1.

Results, Hypothesis 1a: Clinical Diagnosis

Hypothesis 1a states “Students will demonstrate competence by accurately completing a competency task.” Hypothesis1a is upheld. Performance on competency tasks indicates that student teams correctly diagnosed 4/4 cases with a mean accuracy of 92%. Students were scaffolded to these conclusions by inductive flow charts (a decision support tool) and feedback on each decision choice, so their ability to arrive at these ballpark diagnoses must be considered as “assisted.” Since this level of task was reportedly challenging for students, it seems perfectly appropriate that first year students received feedback along each decision point using the decision support tool.

Results, Hypothesis 1b: The Value of VPS for Clinical Decision-Making

Hypothesis 1b states “Students agree (or strongly agree) that VPS are valuable for practicing clinical decision making.” Hypothesis1b is upheld. Exit Survey results data (reported in Figure 47) indicate that most students agreed or strongly agreed that the VPS provided an environment to practice clinical decision making skills in eight dimensions. Students rated the exam preparation aspect lowest (65.7%).

Results, Hypothesis 1c: VPS Improve Clinical Decision-Making Skills

Hypothesis 1c states “VPS improve clinical decision-making skills, as demonstrated by a significant learning gain on a pre- and post-test.” Hypothesis 1c is upheld. Performance on pre- and post-tests indicates significant learning gains of 7.3% and 11.8%.

Results, Hypothesis 1d: Efficacy of VPS vs. Traditional Instruction

Hypothesis 1d states “VPS are more effective than traditional instruction with PPT’s for improving clinical decision making.” As indicated in Figure 47, the results of this test suggest that during this session students receiving traditional instruction made better gains, but the statistical confirmation of effect must be considered by the interaction of modality of instruction and order of instruction. Due to time constraints, another 2.5 hour long crossover session was not conducted in reverse to control for the variable of order. For example, in this crossover session, the Galen group began with VPS. To control for order of modality of instruction, it would have been ideal to do another crossover the next day in reverse order, with Galen beginning with PPT instruction.

There may be another factor that explains this unexpected outcome. Due to the request of the course directors, the heart palpitations workshop developed specifically for the crossover clinical trial required deliberate practice with a lengthy list of about 20 heart rhythm patterns. The pre- and post-tests associated with this crossover study each contained 20 items. Half involved clinical scenarios, and half involved the straightforward interpretation of heart rhythm strips. The identification of a heart rhythm from a rhythm strip is a type of image recognition (pattern matching).

The fact that there were two distinct types of test items and one type involved pattern matching is germane to the validity of the pre and post-test results. The VPS were non-linear, and required synthesizing evidence through inductive reasoning. The ability to pattern match is experience based; it may be taught just as well in a linear fashion with PPT. Although it is a demanding task for first year students to interpret a heart rhythm strip, it is a confirmatory, deductive task. In contrast, VPS were used earlier in the semester to teach inductive clinical reasoning, synthesizing data from a wide variety of sources for one patient case. Since all of the pre-post assessment items did not relate to this type of inductive task, and half involved pattern matching, it is logical that better outcomes resulted from PPT instruction for 20 minutes. Other education research studies suggest, however, that after about 15 minutes, the attention span of learners listening to lectures declines (Prince, 2004).

Assertion 1: VPS Foster Clinical Decision Making.

VPS are effective in terms of supporting clinical decision making in three dimensions: ability to arrive at a ballpark diagnosis, increased learning gains on a clinical decision making test, and student perception of utility. Taken together, all the findings in figure 47 warrant the assertion that VPS foster clinical decision making.

Research Question 2: VPS Mechanisms that Support Clinical Decision-Making.

Research Question 2 investigates “Which mechanisms in the VPS support clinical decision-making?” Chapter 4 presents the process of mixing data collected from 1) transcriptions of student peer discussions, 2) researcher diagrams to explain the flow of decision making, and 3) a story narrative based on the central phenomenon. Combining triangulation approaches described by petite generalization methodology (Barab & Squire, 2004) and diagramming and phenomenon identification processes described by grounded theory (Corbin & Strauss, 2010), together these four data sources provide insight on how game mechanics supported rich discussions among student teams that scaffolded learning and resulted in successful completion of competency tasks. Petite generalizations are not stated at the outset of the study *a priori* as hypotheses; they emerge from the analysis of the qualitative data (K. Wetzel, personal communication, November 27, 2013). Figure 48 provides the sources of the data that warrant petite design generalizations related to research question 2. Disconfirming evidence is presented at the end of the chapter in the summary for all research questions.

Petite Design Generalizations for Research Question 2: "Which mechanisms in the VPS support clinical decision-making?"	**Warranted by**
A. During VPS, students hold rich discussions that align to target competencies for patient encounters.	Transcriptions of student discussions.
B. VPS mechanics such as scheme flow charts, immediate, written feedback, and patient charts scaffold clinical decision making.	Analysis of student discussions juxtaposed with screen captures.
C. The VPS afford students opportunities to assume the role of healthcare team to collaborate on review of the patient case to optimize patient care.	Analysis of student discussions juxtaposed with screen captures.
D. Creating a networked series of learning episodes allows students to experience case solving from several degrees of responsibility.	Pre-and Post-test results and transcriptions of classroom discussion.
E. Tutors play a key role during VPS by clarifying muddy conceptual areas.	Analysis of debrief dialogs, tutor feedback.
F. The central phenomenon of the clinical reasoning experience encountered by student teams during VPS is "synthesizing evidence inductively to make clinical decisions."	Researcher Diagrams Depicting the Flow of Decision Making.

Figure 48. Petite generalizations related to VPS design.

Petite Generalization 2a: Rich Clinical Discussions Align to Target Competencies

Petite Generalization 2a states: During VPS, students hold rich discussions that align to target competencies for patient encounters. Figure 49 presents a matrix student dialog codes, cross-walked to specific national American Osteopathic Association (AOA) competencies. For example, open coding of four student dialogs indicated that students discussed lab and imaging choice 21 different times. The column "AOA Competency #" provides the competency code number. A matrix listing the entire competency statement for each competency number associated with each section of the patient encounter is provided in Appendix P, along with specific examples of student dialog for each segment of the clinical case.

Patient Encounter Segment	Code	Frequency	AOA Competency #
Chief Complaint/	Clinical Presentation (CP) Scheme	11	I.4a
	Prioritize steps of patient encounter	3	II1j
History	Patient History	7	I.3.1.b
Patient Exam	Clinical Pearls Patient Exam	4	III.3a
	Anatomy/Physiology/OPP*	2*	II.1
Investigations & Procedures	Analyze Patient Data	8	III.2a
	Lab and Image Choice	21	I.4i
	Cost of procedures	3	I.4i
Diagnosis	Statement of [ballpark] diagnosis	7	I.4.b
Treatments	Treatments	3	IV.4.b

*Figure 49. VPS d*iscussion topics aligned to AOA competencies

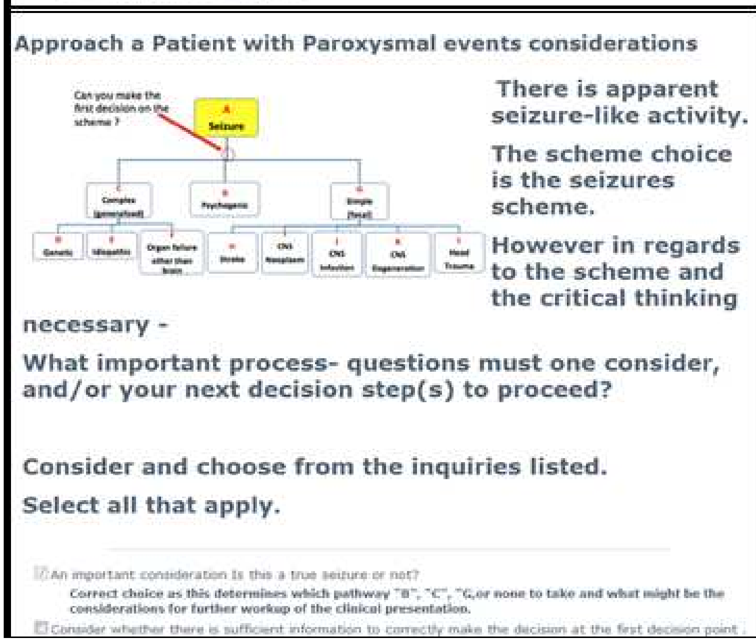
*During VPS, students participated in several conversations about anatomy, physiology and OPP, some of which are documented in this paper. These frequency code counts refer to entire paragraphs associated with these topics, and therefore this count appears low.

Petite Generalization 2b: Scaffolding Mechanisms within VPS

Petite Generalization 2b states: VPS mechanics such as scheme flow charts, immediate, written feedback, and patient charts scaffold clinical decision making. Figure 50 presents student dialog and screen captures representative of those found within the more than

70 pages of transcribed conversations analyzed. In the example below, students review patient data to make a decision along the scheme flow chart. When students select choice options, feedback is provided to them. In other pages of the VPS (not shown), students refer to patient charts (electronic health records).

S3: Craig! EEG, biochemistry profiles.
S3: I mean… this one is tricky. It could be an EEG or it could be all these.
S1: My first thought…
S3: You don't want to do an EEG. That's more like follow up measures, right?
S1: Yeah. Was that in the history? Isn't that like he was witnessed [with seizure], and now he's being evaluated.
S3: Ok. [Agrees].



S3: [Reads the page.]
S2: Seizure.
S1: Return…
S3: It's a true seizure. Yeah. Because it could be… he was observed having a generalized tonic-clonic seizure. Well that could be he was drinking or on drugs?
S1: He was having breakfast.
S3: Are there more than one choice? Let's look real quick. Select all.
S2: I don't know….what do you think?

Figure 50. VPS mechanisms that scaffold students toward clinical decisions.

Petite Generalization 2c: VPS Allow Students to Assume the Role of the Healthcare Team

Petite Generalization 2b states: The VPS afford students opportunities to assume the role of healthcare team to collaborate on review of the patient case to optimize patient care. This generalization emerged from an analysis screen captures and student dialog. Figure 51 illustrates the dynamics of collaboration and consensus building. In this example, the student team discussed a case of lower back pain. In order to make a decision about imaging, they assembled multiple pieces of data from the patient file, but contributed information related to a prior week's osteopathic training regarding flexion of the joint. They also consider recent cautionary advice from their anatomy professor regarding the high cost of an MRI and ask themselves whether the patient will be able to pay for this costly procedure since the patient is receiving treatment at a community health center (CHC).

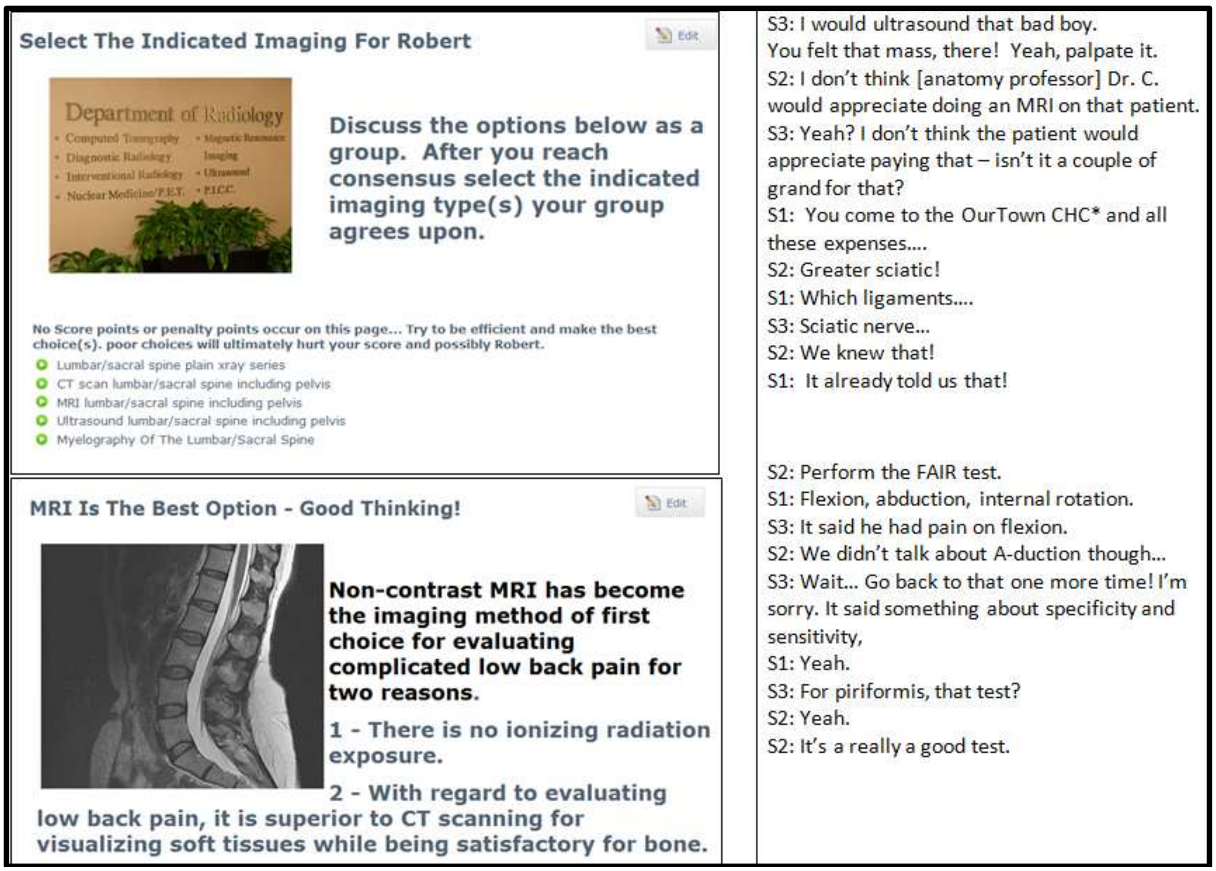


Figure 51. Student discussions about labs, imaging, and anatomy.

Our Town Community Health Center™ is the virtual, fictional location of this patient encounter, supporting situated instruction by providing an authentic setting. These discussions suggest that VPS afforded students opportunities to assume the role of the healthcare team to collaborate on case review to optimize patient care.

Petite Generalization 2d: Networked Learning Episodes

Petite Generalization 2d states: Creating a networked series of learning episodes allows students to experience case solving from several degrees of responsibility. This generalization is warranted through an analysis of classroom discussion both during VPS and during traditional small groups, led by tutors as well as from the pre- and post-test results. Students participated in four networked learning episodes: 1) The VPS, 2) the competency task, 3) the tutor debrief, and 4) the tutor-led case discussion. Education theory indicates that students learn best through legitimate peripheral participation (Lave & Wenger, 1991), meaning that learning is optimized when they have the opportunity to participate as legitimate members of the team, from a safe (peripheral) level of responsibility in solving problems associated with patient encounters. During VPS, students worked in a team of three, with the VPS feedback acting as a faculty tutor, guiding decisions. Next, students completed competency tasks, each individually offering a diagnosis to team members, then reaching peer consensus. Subsequently during debriefs, students had the opportunity to individually ask questions to tutors. Finally, students had another requirement to apply what they had learned through other case discussions led by tutors. Together these networked learning episodes presented a variety of playing fields to co-solve cases from different degrees of responsibility, ranging from minimal risk (peer collaboration) to higher risk (directly answering a tutor-clinician's question in front of nine other peers).

Petite Generalization 2e: The Role of Tutors during VPS

Petite generalization 2e asserts: Tutors play a key role during VPS by clarifying muddy conceptual areas. This theory is warranted by tutor feedback as well as transcribed discussion of the tutor led "traditional instruction." These data revealed that the tutor's role was instrumental. Tutors received preparation before the lesson, and this helped them understand their roles during the VPS. As a result, they ran smooth technology-enhanced active learning lessons in four parts: VPS, Competency Task, Debrief, PPT cases. During the VPS, the tutors acted as guides on the side. They circulated, answered questions, and observed student learning. While tutors were available for questioning in each of the four cases, the four student triads selected for observation asked an average of only one question apiece. During the competency task, tutors ensured that each peer team received the exact same time allowed. Post-simulation, the tutors answered residual questions. Transcriptions of traditional small group sessions revealed that during PPT case instruction, the tutors imparted clinical pearls reflecting a deep level of experience with clinical practice. They focused more on patient history questions, explaining anatomy, microbiology or chemistry concepts, interpreting medical imaging such as X-rays, and discussing the nuances of treatment options.

Petite Generalization 2f: Central Phenomenon

According to Corbin and Strauss (2010), the process of identifying the central phenomenon is a method of analyzing qualitative data to integrate the data into new theory. As described in Chapter 4, the central phenomenon is developed by the researcher through the process of thinking deeply about the data and researcher memos. The researcher engages in a process of micro-analysis diagramming, looking for associations among the codes (Corbin & Strauss, 2010). Similar to the process taken by attorneys in proving a case, the researcher assembles the data to explain the sequence of events, thereby summarizing a plausible story or narrative of the entire experience under study. In this circumstance, the experience under study is the manner in which VPS support clinical reasoning. Petite generalization 2e asserts “The central category or phenomenon that summarizes the student experience of this implementation of VPS was ‘synthesizing evidence through inductive reasoning to make clinical decisions’.

The Decision Sequence. For researchers who synthesize thoughts well through visual display, diagrams assist in connecting relationships among the data (Corbin and Strauss. 2010). Figure 52 provides a researcher diagram of a sample ‘decision gauntlet’ during one case. For simplicity’s sake, Figure 52 presents the decisions in a linear fashion, when in actuality, during the VPS under study, most decisions presented in a branching fashion. This diagram (Fig. 52)

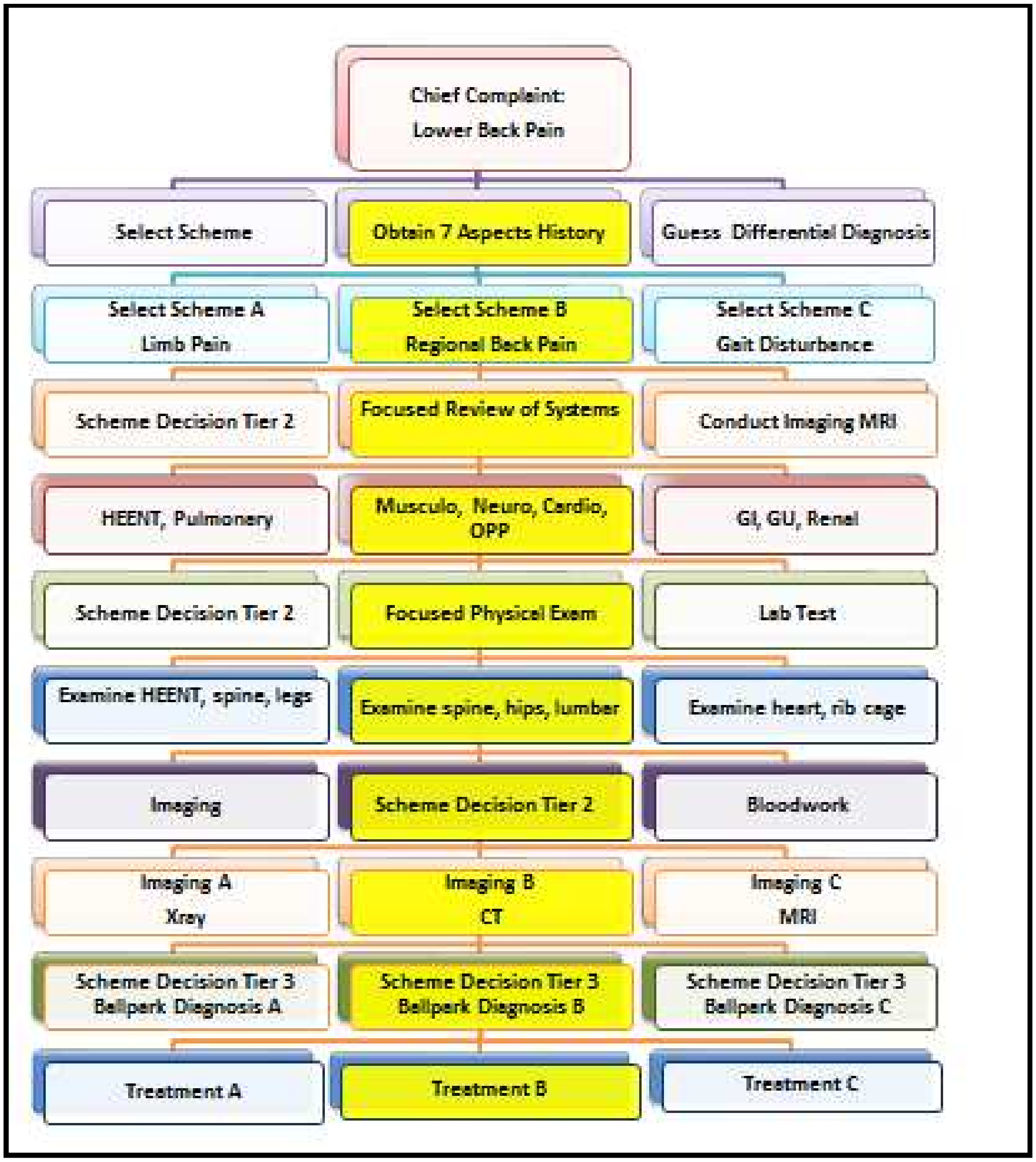


Figure 52. The decision gauntlet: 10 sample decisions encountered during one VPS. (McCoy, 2013.) Osteopathic Principles and Practice (OPP). Head, eye, ears, nose, throat (HEENT), Genitourinary (GU).

demonstrates that the VPS required students to make key clinical choices through the full range of a patient encounter.

In reviewing the connected transcriptions of student conversations and the sequence activities, the story was similar. Discussions revealed that students collaborated in analyzing the case through inductive reasoning. With almost no tutor scaffolding, they quickly formed a team of three, opened the case player, stepped into the role of physician (often assuming a professional tone), and proceeded to collaboratively interrogate the patient data. Due to the branching, non-linear design of the VPS cases, students were required to agree upon on the order of investigations, as well as prioritize lab and imaging investigations. During this inductive process, students struggled to make meaning. They assembled evidence from many sources including large group course content, the patient charts, patient lab tests, personal experience, and scheme flow charts. In completing the VPS, students negotiated a gauntlet of key decisions. Decisions were scaffolded by graphic organizer diagrams, feedback they received after selecting each choice in the simulation exercise, and peer consensus. This process reflected skills required of 21st century physicians working in an inter-professional team: skills of negotiation, communicating with respect, and verifying assumptions through conversations regarding patient data (IPEC, 2012).

Research Question 3: Collaboration

Research question 3 inquires “In which ways do VPS foster peer collaboration?” This question was answered by triangulated data from the Exit Survey, photographs of VPS sessions, researcher observations, transcriptions of student discussions, and tutor feedback. Evidence presented in Chapter 5 from these data sources warrant Assertion 2.

Assertion 2: VPS Foster Collaboration in Eight Dimensions

Figure 54 summarizes the key *a priori* elements of collaboration (as presented on the exit survey), and where available, provides at least one other source of data confirmation for each element. In completing the Exit Survey, students provided high ratings in evaluating aspects of the VPS exercise related to collaboration. As reported in figure 53, most students (83.7%), agreed or strongly agreed that the VPS supported these elements of collaboration. These student Likert ratings were corroborated by other data sources. Student dialog and researcher observations confirmed that in general, students communicated respectfully and encouraged each other to participate. Student dialogs and tutor feedback reflected consensus discussions, team spirit, and cooperation.

Exit Survey Items Related to Collaboration	Confirmed by
1. Other group members communicated respectfully with me. (94.3%)	Student dialog
2. I communicated in a professional manner using respectful language. (91.5%)	Researcher Observation
3. I encouraged other members on the team to express their opinions. (88.6%)	Student dialog
4. Brain-storming with fellow medical students was helpful. (87.7%)	Student dialog Tutor feedback
5. Group decision making was useful. (86.5%)	Tutor feedback
6. Team discussion clarified concepts. (85.7%)	Student dialog
7. Working in a small team of 3 allowed better participation than working in a team of 10. (84.8%)	Photographs
8. I put in a lot of effort. (83.7%).	Photographs

Figure 53. Elements of collaboration supported by VPS activities.

These data sources provide additional evidence that brainstorming and group decision-making were helpful. Analysis of 295 photographs during VPS indicated most students were focused and putting in a great deal of effort when working in a team of three.

Research Question 4: Engagement

Research question 4 probes "In which ways do VPS foster engagement?" This question was answered by triangulated data from the Exit Survey, Photographs of VPS sessions, Researcher Observations, Literature, and Tutor Feedback. Evidence presented in Chapter 5 from these data sources warrant Assertion 3.

Assertion 3: VPS Foster Engagement in Eight Dimensions

VPS foster engagement in eight dimensions. Figure 54 summarizes the key *a priori* elements of collaboration (as presented on the exit survey), and determines at least one other source of data confirmation for each element. Student ratings from the Exit Survey reflected reasonably high ratings for the engagement aspects of VPS. Data collected from the electronic Exit Survey inform this question. Overall, students found this VPS modality most valuable for new experiences and for providing variety. As reported in figure 55, students *agreed* or *strongly agreed* that the VPS supported these elements of elements at a minimum of 60.6%, but the efficacy of VPS for fostering engagement was corroborated by other data sources.

Exit Survey Items Related to Engagement	Confirmed by
1. They added variety to the learning environment. (92.4%)	Tutor comments
2. I enjoyed working on the tasks. (85.6%)	Photographs
3. They provided exposure to new experiences. (78.8%)	Student Dialog
4. They provided relevant feedback. (78.1%)	VPS Screens
5. They increased my interest in clinical practice. (71.5%)	Student Dialog
6. I did not realize how time passed. (67.3%)	Photographs Researcher
7. I found the tasks to be quite exciting. (63.5%)	Photographs
8. I was completely absorbed in the activity. (60.6%)	Photographs Tutor Feedback

Figure 54. Elements of engagement supported by VPS activities.

All of these dimensions of engagement are corroborated by literature from game theorists, indicating that this generation benefits from a variety of teaching modalities in the learning environment (Prince, 2004; Cullen, Harris, & Hill, 2012). Literature from the fields of situational learning (Lave & Wenger, 1991; Vygotsky 1978) states that students will benefit from relevant feedback and exposure to new experiences. Analysis of 295 photographs during VPS indicated most students were focused when completing these exercises, an indicator of “flow” or absorption in task. The fact that students wanted to continue playing through the simulations was evidence that although students did not forget about the time (because it was a timed activity), they enjoyed it enough to want to continue. For example, after completing the competency task, triads would typically return to the case to finish the treatment section and review their final score. Only if they received a score of 90 or better would they encounter their reward video. The reward video was a gamification element added by case authors as a motivation. This device was a funny 1-minute video to play as a trophy for earning a high score. In every case, after the 20 minute mark, students revealed their interest by volunteering to return to the case and finish the treatment section. In each of the four sessions transcribed, there was additional evidence of engagement by strong focus on task, humor, and even team spirit. In summary, reviewing input from a 360 perspective, these data indicate that VPS fostered engagement. Students felt they were moderately to highly engaged, and tutors felt students were engaged and enthusiastic. Researcher notes, corroborated through photographs indicated that students were highly participatory.

Research Question 5: Improving the VPS Activity

Research Question 5 analyzes how the lesson should be improved. The Exit Survey revealed student input through their open responses to this question: *How could this lesson be improved?* Observation notes and memos from the four VPS sessions provided additional insight.

Assertion 4: There are Seven Proposed Design Solutions

Upon consideration of the residual issues reported from several data sources, design solutions for the next implementation of VPS (Fig. 55) are presented as follows.

Issue Category	Note	Design Solution
Time Constraints	Students and tutors expressed 20 minutes was not long enough for finishing certain cases.	Provide the option to continue beyond 20 minutes.
Case Content	Students and tutors request that medical content must fully align with content taught during the week in large group.	Continue to refine the cases to match specifics of large group content.
Case Format	Student dialogs, exit survey comments, and tutor feedback confirm that some of the VPS cases are still too lengthy and complex. There is still too much text on the page, and there are extraneous review pages. Some of the feedback should be more specific. Provide a way to auto-access the electronic health record.	Strengthen the process that cases should be submitted two months early and undergo a thorough review and proofing process, and that they adhere to posted style sheet guidelines.
Activity format	When three triads are in one small group room, the sound of video media is too loud.	Student triads should meet in separate spaces or be able to listen via headphones.
Learner preference for individual play	Some students indicated that they want to complete the DS alone.	Provide a library of cases on Blackboard for individual practice after the collaborative sessions.
Technology	Tutors expressed a wish for the VPS to be accessible through the learning management system (LMS), Blackboard.	Integrate VPS with LMS.
VPS activity frequency	First year responses from a cohort who received more than 20 VPS was less enthusiastic than those receiving only four in the first semester. Tutors request a maximum of one VPS per session, and not more than two per month.	These data suggest that about six VPS per semester might be acceptable to both faculty and students.

Figure 55. Design solutions for improving the next implementation.

In terms of time constraints, 20 minutes was not always enough time for completing VPS.

These data suggest that next implementation, either the cases should be further streamlined or tutors should have the option to allow more than 20 minutes of VPS. VPS authors have made progress in aligning VPS case content to precisely match the large group instruction, but cases should be further refined through a process of peer review by clinical faculty. In some cases, the amount of reading required impeded discussion. Prior to the second implementation, authors referred to case-writing guidelines and refined the simulation pages to reflect more concise text; they require additional revisions to further simplify pages with too much text without reducing the sophistication of the content. Since students of all levels would like to access these cases for individual study, and some students are distance learners, it might be helpful to post them in the learning management system as a library. Since the students at this site receive didactics via Blackboard, it would be best if the cases were directly accessible within this learning management system. Finally, at this point in the adoption of this innovation it is critical to listen to stakeholders such as students and faculty. Input received suggest that to increase buy-in and avoid burn out with this particular activity, it is best not to over-prescribe VPS during weekly case practice, but intersperse them throughout the courses, with a maximum around six per semester.

Summary of Disconfirming Evidence

Clinical Decision-Making

Disconfirming evidence that students improved their clinical decision-making through VPS is mainly reflected in the comparison study results. Students receiving instruction via PPT for 20 minutes made better learning gains than counterparts studying via VPS. These results must be considered cautiously considering that during the first implementation crossover trial, students receiving VPS made better learning gains, while not significant ($p=.06$). Assessment items and case content used in the first implementation trial more closely resembled full clinical scenarios. Disconfirming evidence for VPS fostering rich clinical discussions pertained mainly to the level of confusion and “struggle” required during these sessions.

Constructive Struggle. Education research indicates that a measure of intellectual struggle is healthy, and is especially associated with short term failure for complex or abstract tasks

(Kapoor & Kinzer, 2009). For example, some segments of student VPS dialog included expressions of frustration and confusion in synthesizing and prioritizing of investigations. However, after the sessions, students had the opportunity to debrief with their tutors and clear up confusion. Some students held intense debate regarding the best scheme path and wondered whether the scheme was correct. This part of the student dialog related to scheme path debates may be construed as healthy intellectual consensus seeking.

Dissonant Struggle. Other parts of the student dialog pointed to elements that cognitive overload (Clark, Nguyen & Sweller, 2006) thousands of words of text, lack of a timer, too many “teaching pages”, ambient noise, team members talking while others were trying to read. In the future, designers should streamline these VPS to avoid some of the elements causing dissonant struggle and cognitive overload. Some students seemed surprised at the amount of work to do in 20 minutes and the challenging nature of the tasks. However, in the field of primary care, it is common knowledge that fast thinking and intense data collection is required during patient encounters of duration less than 30 minutes. These training episodes build capacity to remain calm under pressure in a hectic, loud, collaborative clinic environment. Students were scaffolded by ‘more knowledgeable’ peers and immediate feedback.

Collaboration

Evidence that VPS do not support student collaboration is mainly reflected in two facets: team formations and the sophistication of collaborative dialog. In terms of team formations, a few tutor and student comments on the Exit Survey said that when there were three student teams in one room, there was too much noise, especially from video. In terms of the sophistication of dialog, in some cases, some of the student dialog with respect to references to the case could have been more refined. In some instances, students admitted not remembering information or expressed confusion. In other cases, students struggled to cogently express their thoughts. VPS activities provide opportunities for professional, collaborative discussions.

Engagement

Evidence that VPS do not support student engagement is mainly reflected on lower ratings on the exit surveys with respect to flow elements such as absorption in task (62% for the 2016 cohort). However, this percent of personal impression of flow may seem high in view of the survey response rate (97%) and the time of year this survey was implemented (three days prior to the final exam of the year). Photographs and tutor comments provide a different perspective; students appeared to be absorbed in the task and focused on the activity. A few students indicated that sessions with tutors were better. For these two reasons, the entire body of data from two implementations suggest a measured, balanced approach to integrating VPS into some case practice sessions, keeping them streamlined and brief, and allowing opportunities for students to interact with their clinical tutors as much as possible.

Optimal Sequence of Networked Learning Episodes

The pre- and post-test results indicated that the Hippocrates group, who received tutor instruction with their clinical tutor via PPT, scored higher than those receiving VPS instruction. This suggested a restructuring of the networked learning episode sequence as follows (Figure 56). This new map suggests that the ideal sequence of instruction should be as follows:

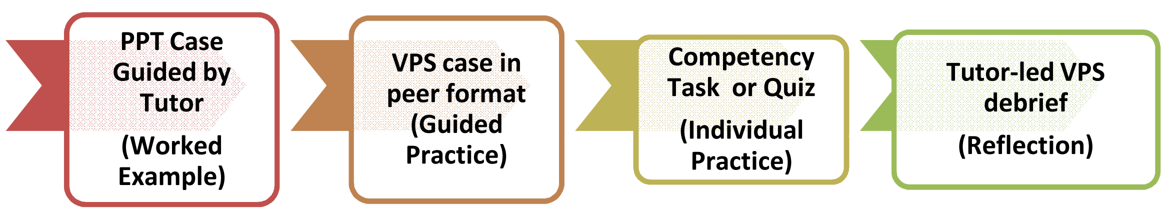


Figure 56. The optimum sequence of networked learning episodes. McCoy, 2014.

More study is required to corroborate this theory. However, this sequence of instruction is supported by education theorists such as Merrienboer and Sweller (2005) who theorized that the optimal teaching sequence should be: *1 – worked example*, *2 – guided practice*, and *3 – Individual formative skills check, using a transfer case*. Following team based learning methodology (Michaelsen et al., 2008), another technique for readiness assurance is a brief pre-quiz administered prior to application of skill exercises. These researchers suggest that readiness assurance quizzes should count toward the student's grade. Readiness assurance may alleviate anxiety, since students may feel more confident with the case lexicon, anatomy, images, pharmacotherapy and treatments.

Findings from this research study suggest the following timings for the networked sessions: 20-30 minutes for the first case, (a worked example case in PowerPoint or other media led by a tutor), 20 minutes for a related VPS, followed by 5 minutes for the competency task, followed by more time to complete the VPS as needed, followed by a tutor debrief (as short or long as needed). Through analysis of student discussions, a problem of practice emerged that some students read fast and others read more slowly. For this reason, it was important to provide a 20 minute time limit in order to control a level-playing field for the competency task. However, by allowing flexibility for each tutor to decide whether to allow the students to continue through the VPS, the tutors were self-directed and their opinion validated. This strategy of allowing them choice seemed to work very well. An analysis of observation records, the tutor feedback, and the subsequent debrief and tutor-led case, suggested that the lesson plan as described above will perform well in the future to support learning as a networked sequence of events. Providing a debrief after the competency task, followed by a tutor-led PPT case worked during the second implementation as a successful lesson sequence, since the three formats for discussion provided complementarity by looking at the same clinical presentation from four angles.

Chapter 7 - Conclusion

Introduction

Chapter 6 reported the study conclusions by answering the five research questions based on warranted assertions. This chapter provides a discussion regarding the implications of this research project. The first section, *Implications for Practice*, considers how the findings of this study contribute to educational practice and corroborate existing literature. *Limitations of Current Study* reviews the limitations of this research study and their implications for reliability and validity. *Future Research and Development* contemplates possible areas for continued research and design innovation. Finally, since this project was an education leadership and innovation project, *Reflections on Leading Change* shares researcher revelations regarding leading the development of an education innovation.

Implications for Practice

This research study supported a unique, scheme-inductive VPS intervention, with the overall goal of enriching the pre-clinical curriculum. Through this project, first year students safely gained practice in learning to reason like expert physicians during simulated patient encounters. The results of this study support the theory of situated learning and legitimate peripheral participation (Lave & Wenger,1991), indicating that VPS foster clinical decision-making, collaboration, and engagement.

Clinical Decision Making

Specifically, this education intervention attempted to address a problem of practice related to the need for additional deliberate practice with clinical decision making during case practice in a small group setting. This objective was accomplished through three cycles of testing a new innovation, and the development of a new series of VPS. Case authors designed the VPS to support a scheme-inductive reasoning process. In light of study results, this still seems like a strong approach, given the fact that first year student triads participated in problem solving at solution-critical moments (Barron, 2002) and were able to negotiate accurate ballpark diagnoses. While the competency task at the end of each case was helpful, it would be optimal to design the sessions to require students to explain their reasoning. This modification would be time-intensive for faculty. The study revealed that the topics of clinical discussion held by students during VPS sessions were valid, since they align to AOA competencies (AACOM, 2012). In the future, it would be useful to investigate whether the level of discourse among first year students displayed during these sessions may be considered advanced in comparison to discourse generated by first year students at other medical schools. It would also be useful to design a transfer case to see if students were able to re-apply their problem-solving schema.

This study suggests that problem-solving tasks within the patient encounter are both inductive and deductive; both methods of reasoning are important. For example, assembling evidence from multiple sources to reason toward a diagnosis is inductive and exploratory, but the task of interpreting a heart rhythm strip is deductive and confirmatory. If the design of VPS supports inductive reasoning, it is best to design the pre- and post-test assessment to reflect inductive, not deductive reasoning tasks, in order to more accurately test the theory that an inductive VPS increase clinical decision-making skills. This point is corroborated by assessment development literature in the realm of construct validity (Messick, 1990). Assessment developers must align the relevance and representativeness of the test items and tasks to the competency domain being assessed.

Peer Collaboration

This intervention also attempted to increase peer collaboration to meet inter-professional collaboration competencies. Students received collaboration guidelines prior to case practice. During VPS, they were obliged to select options reflecting consensus decisions. This study measured specific attributes of collaboration displayed during VPS patient care discussions. Constructivists assert that students benefit from discourse with peers, who bring a different perspective or more experience (Gergen, 2009; Wenger, 1998; Vygotsky, 1978). Students co-construct meaning: concepts and connections become clear when students restate facts, ask questions, articulate reasoning, and are tasked with achieving consensus on decisions (Aufschnaiter, 2003). These theories were confirmed through the results of this study. When students are requested to generate work products or engage in thoughtful collaboration during VPS simulations, these activities exercise different cognitive muscles than those activated when receiving knowledge from the professor or peers. This study also underscored that peer learning has merits, even when faculty are present and can teach a lecture or lead small group. These results corroborate findings regarding the value of team-based learning (Michaelsen, Parmelee, McMahon, & Levine, 2008).

Engagement

Another study objective was to investigate whether VPS increase student engagement during case practice (research question 4). From the results of this study, it was evident that students were focused on the task at hand, an indication of flow (Admiraal, Huizenga, Akkerman, & Dam, 2011). They were highly participatory, displaying very little social loafing (Piezon & Donaldson, 2005). This was corroborated by the student exit survey responses, indicating that working in a team of three provided more opportunities for participation than in a team of ten. On the same survey, a majority of students indicated that this activity provided variety, confirming active learning theory (Prince, 2004). While the students were highly focused on the clinical tasks, these tasks were challenging. This phenomenon may reflect a state described in the literature as cognitive engagement (Rotgans & Schmidt (2011), and merits further exploration in future studies.

Limitations of the Current Study

Pre-Post Test Results

Aside from the small sample size of 108, the major limitations of this study lie mainly in the realm of the randomized, controlled trial segment. Due to time constraints, the assessments were limited to 20 items apiece. This resulted in low KR-20 statistics for individual test items, as reported in Appendix Q. For this reason, the reliability of the assessment is not as high as might be desirable. Furthermore, the pre-and post-test scores associated with this study did not affect students' grades. This leaves open the question as to whether the students were highly motivated to score highly during these assessments. For the next implementation, course directors should count pre-and post-test results toward course grades. Due to time constraints, it was not possible to implement a double crossover design. Two cases and two sessions of pre-and post-tests required two and a half hours, which is a significant time allocation within a very compact curriculum. Due to not completing a double crossover, the order of mode of instruction had an effect. The silver lining of this realization supports new petite instructional theory that the order of mode of instruction has a significant effect, leading to a theory regarding the optimal sequencing of networked activities.

Due to the time frame of the study and the opportunity that was offered to implement VPS during a palpitations workshop, the pre-and post-test content was not as complementary to inductive approaches to clinical reasoning as it needed to be. These assessments included many items requiring basic interpretation of heart rhythms; this is not an inductive task. In the future, it might be possible to compare results among item task types (clinical scenario vs. lab or image results interpretation). Due to constraints regarding power statistics, it was not possible to do the crossover study with small groups of 10, and therefore the crossover study took place in a large group classroom, taught by one instructor with a PPT from the podium. Therefore, both comparison groups received instruction from the same professor during traditional instruction. This situation had validity advantages; the comparison groups remained stationary and stable and had no chance to intermingle. The level of instruction was equal among comparison groups. However, it cannot be generalized that the quality of this one professor's instruction was the same as that of other clinical tutors.

Another important factor relating to student questioning during the clinical trials. During this clinical trial, students had opportunities to ask questions to this professor during the 20 minute case presentation via PPT. During the VPS segments, however, students did not have the opportunity to ask tutors questions. For the next implementation of a crossover design, it seems important to allow opportunities for asking questions during both VPS and traditional comparison group sessions, as was feasible during the Fall Field Test.

Third, during the clinical trial, first test session, one of the item images was absent. This test item (#6) was subsequently removed from the pre- and post-test results data. In the same session, three of the students forgot to bring laptops on the pre-post day, and their test responses were logged on paper test forms. This made it made it too time consuming for assessment staff to append these data to the statistics report generated from ExamSoft. For this reason, the KR-20s and other item statistics were analyzed with an n of 104 (See Appendix Q).

Generalizability

The generalizability of a study's findings refers to the degree of transferability to other settings (Herr & Anderson, 2005). The assertions and petite design theories generated from this study must be considered as naturalistic generalizations (Stake, 1995), meaning they are generalizable to the specific study context. While results from this study may be considered valid for the study site, they cannot be generalized to a wider population. That being said, these findings were supported by data triangulation. They may be of use to other investigators in designing studies or in testing theories in new contexts. In attempting to apply these methods and findings toward an innovation in a different context, investigators should consider the specific constraints, VPS employed, outcome measures used, and the natural environment of the study setting.

Unforeseen Events during Practice Sessions

Four unforeseen events occurred during data collection during the spring implementation. Log on issues occurred for one or two students during practice sessions. Since VPS were practiced in teams of three, no student teams were unable to access cases during case practice. During the fourth day of VPS practice, the recording system, Arcadia, failed to record the event. Nonetheless, the session was implemented according to plan, including a full observation from the control room. In order to meet the quota of analyzing four segments of student discussions, it was necessary to substitute this session by transcribing a second student discussion from the third practice session. An unexpected pause in internet connectivity suddenly closed the VPS case for two minutes on the fourth practice session day for a few groups of students. Tutors added two minutes to their timed, 20-minute session. Finally, in one session observed, a tutor handed out the competency task two minutes later than the 20-minute mark and did not collect it back promptly. However, this only affected one team score out of more than 140 competency task scores. This episode demonstrates the importance of tutor preparation and challenges inherent conducting a rigorous experiment in a live, technology-enhanced classroom.

Future Research and Development

VPS Design

Scaffolds. Although OMSI students exhibited a measure of struggle through these sessions, for the most part, teams were able to solve cases in 20 minutes with the assistance of scaffolds such as scheme diagrams, health records, and feedback. One of the most interesting findings of the study was that students were interested in exploring wrong choices. In the future, VPS can be designed in years OMSII-IV with less scaffolding. Fading scaffolds, described by Sherin, Reiser, & Edelsen (2004) is a recommended method for increasing competence by gradually reducing scaffolds.

Branching vs. linear cases. This study revealed that both branching cases with peer collaboration and linear PPT cases with tutor-facilitation have advantages. They are complementary, as revealed in Figure 45. The discussion regarding the way that these VPS were specifically designed to branch fell outside the scope of this paper and would be an excellent future research and design topic. This study touched upon the differences between areas of concentration among VPS and traditional tutor-led discussions. Another paper might address the preparation of small group tutors in their role as facilitators of virtual patient simulations.

Concentration of VPS in the curriculum. This study involved two implementations of VPS. The field test implementation occurred during the very last few weeks of the first year of medical school. As a result, participants communicated via exit survey comments that they were somewhat burned out from completing approximately 15 VPS during the first year, some of the simulations 45 minutes in length. In contrast, during the fall main study, after only four 20-minute

VPS sessions, student comments reflected more enthusiasm for VPS. This indicates that it is best to provide a maximum of one 20-minute virtual simulations per session. The findings of this paper may contribute to theory related to the optimal frequency and duration of VPS for different levels of learners.

VPS templates, guidelines. and style sheets. VPS have the potential to be shared among institutions (Ellaway et al., 2008), but this involves style sheets and standardization. Clark et al. (2006) noted that design specifications and standardized elements are important to the overall learning effectiveness of the VPS series. During the course of this project, the TEAL team reviewed the Decision Simulation Style Sheet (2013), and developed a SOMA VPS style sheet. Going forward, it seems important for simulations to be peer-reviewed and proofread more closely. Though the design team co-constructed a style manual and improvements were made to meet design specifications, there is certainly room for improvement in terms of streamlining text, refining feedback, and improving peer review processes.

VPS and assessment of competency. The data collected through this study were extensive, and it was not feasible to share all of it through this dissertation. Team scores for each VPS session may be considered at a later date. While Decision Sim VPS include a report function that tracks individual student decisions and competencies, during data collection, the 100-point scoring system designed by the TEAL team was still in field test format during the second implementation. To prevent the scope of the dissertation from broadening too widely, I reserved the exploration of the system and the scoring rubric that is the foundation for the 100-point scoring system for a different research paper. In the future, it would be helpful to be able to share (via proper protocols) results from each session with the students and the small group tutors. Furthermore, it would benefit all to print reports from the VPS that indicate the aggregate weakest areas so that the tutors can address the muddy points. TEAL team efforts in 2013 related to assessing discreet clinical skills in history taking, physical examination, and lab/imaging investigations. This design offers potentials related to assessment related to discrete competency areas as described by Shute et al. (2010).

Gamification elements. This research uncovered exciting potentials for VPS in terms of gamification. This study revealed that students were motivated by gamification elements such as timed tasks, point system, multi-media, story line, and dramatic elements (Deterding & Dixon, 2011). However, exploring these designs in detail fell outside the scope of this paper. Results from this study point to design enhancements such as streamlining text, adding navigation tools, and refining elements of virtual reality to raise the fun factor and enhance the student self-perception being immersed and "absorbed in task."

Community medicine theme. According to Jerome Groopman (2007), it is time to revise medical training, by using explicit means to teaching medical students to diagnose more effectively: by listening more carefully to patients, sifting through evidence using an extended history and patient centered approach. The VPS under study were designed to support these goals, but future studies must be designed to test these hypotheses. Another direction for future research lies in the potential use of VPS to increase the student's awareness of patient care best practices in community health centers. SOMA students study at or near community health centers in OMSII-IV. While some of these VPS cases were set in community clinics, the emphasis was more about clinical decision making than patient care options in these settings. However, this research study uncovered a strong potential use of VPS for teaching community medicine. For example, the SOMA VPS case "Marco Rodriguez" was designed as branching training episode. This case was set in a rural California community health center, and practiced achieving positive healthcare outcomes. Another aspect of this case was the inter-professional collaboration among physicians, dentists, and social workers. In the future, these strands (health outcome and inter-professional resources), may be incorporated in the VPS series more extensively to improve student ability to achieve excellent patient health outcomes in community medicine settings.

Learning Domains

Inductive Reasoning. In the future it would be useful to study whether there are delayed effects of inductive reasoning training, such as deep learning (Kapoor & Kinzer, 2009). VPS practice provided first year students with a grounding and orientation in this reasoning mode, but the true product of this training may bear fruit in the remaining years of medical school (Patel et al., 2004; Schwartz et al, 2012). For example, these sessions provided students with direct experience in being able to quickly and efficiently take command of the sequence of a case encounter, prioritize key evidence, and arrive quickly at general diagnosis, an important skill described by expert clinical diagnosticians such as Dhaliwal (2012).

Interactions among Learning Domains. This study inspired the generation of this researcher diagram (Fig.58).

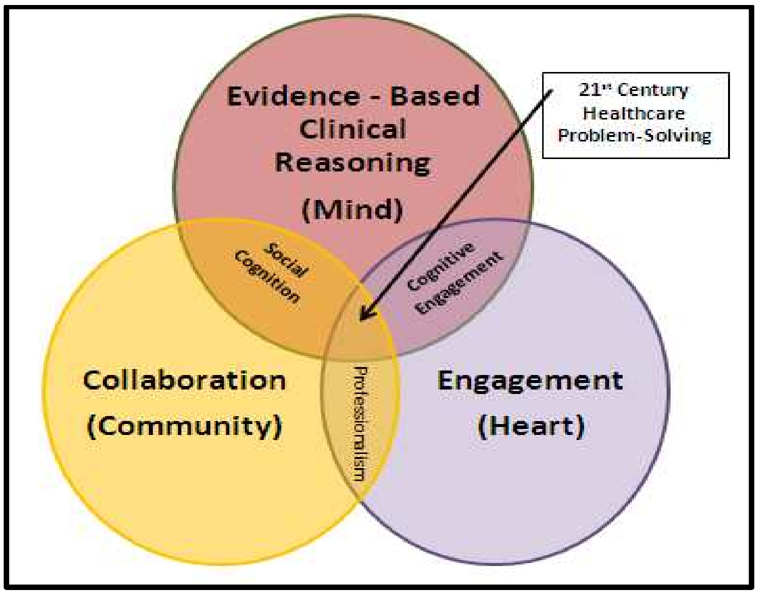


Figure 57: Interactions among Learning Domains

Figure 57 raises several potential research questions: Are there inter-relationships among these three domains: reasoning, collaboration and engagement? If so, how should the interrelated skills be characterized? Do they align to constructs identified in the literature as cognitive engagement, social cognition, and professionalism? What motivates medical students to persist at a high level of engagement in their medical careers?

Reflections on Leading Change

A fifth project objective was to ensure that the new education innovation (scheme-inductive VPS) integrated successfully into the existing curriculum and was tested through a transparent, continuous quality improvement program. This objective was carried out successfully by iterative improvement cycles and design-based approaches (Barab & Squire, 2004). As Assistant Chair of the TEAL team, I used collaborative and leadership strategies from Wenger (1998), Fullan (2011), and Senge (1990). From Wenger, the important step of forming and consolidating a Community of Practice (the TEAL team) nurtured and sustained the project. From Fullan, I followed advice about ensuring clear communication, specific goals, securing buy-in, and weathering through the difficult phases of implementation. Senge's advice about seeding the innovation properly within all the interconnected, integrated systems was influential to my leadership approach in implementing this education innovation.

Curricular Validity

Planning far ahead to embed the practice activities in courses was critical. Obtaining consent to integrate VPS in OMSI courses involved meeting with course directors and ensuring enough time for the cases to be written and reviewed. Aligning the VPS precisely with other content being taught in the general curriculum required authors reviewed through 40 hours of large group lectures and current clinical guidelines in order to write each individual VPS module.

Buy-in From Clinical Tutors and Other Stakeholders

One of the main challenges I faced as a leader was achieving continued buy-in and seamless integration of VPS within small group case practice. To optimize this process, I built rapport by explaining the project carefully to around ten faculty physicians (small group tutors and others supervising them). I learned that it was very important to listen well to fully understand their culture, views, and beliefs regarding case practice. Originally, tutors were unsure whether VPS would be worthwhile and were concerned that they, the master clinicians, would not be required during VPS sessions. Gradually the tutors witnessed, first-hand, that students were engrossed in the VPS. As a result, tutors wrote mainly extremely positive feedback, especially once they could circulate among the students and lead the case debrief. I found that for some, the technology learning curve was steep. As a result, few of the tutors accessed the cases on line prior to the session. They were used to receiving the case via PPT. To address this, the VPS team attended the case preparation sessions, and VPS authors walked tutors through each case. I printed instructions for each session to help tutors remember to distribute competency tasks and submit feedback. The tutors appreciated this tool kit. It was helpful to train these tutors a year in advance of the final implementation. As a result, the clinical faculty involved did an amazing job, performing in their new roles smoothly for the final implementation. I will always be grateful for their dedication.

Aside from the tutors, seeking the opinions of curricular leadership was extremely important. Briefings, meetings, diagrams, and results data were effective tools for explaining the need for change. I learned that although the field of educational games uses specific jargon, we educators should avoid using it to communicate clear messages. During trainings, it was better to explain pedagogy succinctly to others without jargon such as “scaffolding,” “recursiveness,” “knowledge encapsulation”. This strategy is consonant with Fullan’s (2010) principle of explaining the project in simple terms. However, in explaining the project to administration, it was always fruitful to relate the goals of the project back to the education mission and school’s strategic plan.

The Importance of Clinical Tutors

Over the three year period, the school added emphasis on small group case practice, hiring a small groups’ leader. Some might consider this a secondary effect of a technology-enhanced innovation: that traditional instruction improves to keep pace. The original intent of the intervention was not to set up a competition between traditional teaching skills and VPS, but to provide variety among classroom activities. However, due to the rigors of a comparison design, I ended up transcribing four sessions of traditional case practice. Through conducting this research, I found the role of the tutor extremely valuable—even during VPS—and was astounded by the quality of student inquiry during the traditional sessions I observed.

Stakeholder Review

After compiling the study results, I shared the study findings with all of the medical school faculty in an open forum during a “stakeholders feedback session.” Providing transparency by sharing the evidence based results of the innovation project is a leadership strategy (Fullan, 2011), but it is also is a form of member checking to ensure that stakeholders agree that the claims are supported by the evidence (Stake,1995). During this session, attended by twenty faculty participants, no objections were raised. One expressed that the VPS seemed useful as activities providing variety within the curriculum. When asked, participants agreed that it might be useful to conduct further cycles of research and did not rule out a future randomized control trial design. Others suggested the following further research topics.

- Integrating VPS with electronic health records (EHR), asking students to complete these EHR during the simulations, and then later conducting research to prove student learning through data collected via electronic health record notes.
- Investigating whether students remember the case better when the case is contextualized with elements such as patient name, family members, and dramatic story line.
- Exploring the delayed learning effects of struggle and deeper thinking involved in completing VPS.
- Investigating whether participating in VPS results in better course grades.
- Encouraging extended play, supporting student curiosity in exploring more pathways of the simulation.
- Investigating the relationship between learning style and attitude toward interactive learning.
- Exploring the relationship between VPS instruction and success on different types of assessment items: inductive, deductive, higher order, etc.

Team Work

At key production moments, it was challenging to orchestrate rigorous performance from a large group of key players (tutors, case authors, ITS technicians, Decision Sim technical assistance, students). Keeping the project on track involved extensive communication as described by Fullan (2011) to ensure that all stake holders were on the same page. Exchanging frequent email and holding regular, weekly meetings kept the case authors working at a brisk pace to finish the cases. Every month, I shared journal articles about VPS design with the TEAL team. Project management strategies included backward design to create timelines, milestones, and rehearsal dates. A detailed research journal shared with the dissertation team provided a forum to memo about interesting ideas regarding clinical reasoning and VPS design theories.

Technology Glitches

For any technology activity involving multiple small group rooms, there is the inherent risk of total or partial system failure. There were elements of the technology that were not in my direct control. It was necessary to rely on others to video record the sessions, publish the VPS cases to the students, ensure auto-play of video or audio embedded in the VPS, and manage the pre-and post-test data within ExamSoft. Consequentially, it was very important to schedule a field test rehearsal six months prior to the implementation due date, particularly the crossover trial. My advice to other innovation leaders is that the implementation plan should include field testing and backup plans. Strategies used included extra data collection days in case one or more technology systems failed on “game day,” assiduously refining data collection instruments, and scheduling dry run-throughs with ancillary technology systems. It was valuable to take photographs of the active classroom environment, but this required planning far in advance for obtaining permission for VPS screen captures and digital media.

Leading Research

This researcher’s journal notes document a time commitment of three and a half years of innovation research, development and implementation. Following a design-based cyclical approach (Barab & Squire, 2004) the first year included a literature review and landscape analysis, development of the prototype, and a beta test. The next two years involved a field test, data analysis, instrument refinement, final implementation, followed by another cycle of data analysis. Students enjoyed the VPS sessions much more during the second implementation, once the glitches were ironed out. The change in their attitude was refreshing and surprising. It affirmed the utility of the design-based research process. This study piloted a clinical trial model, including comparison groups and a repeated measures sequence for assessing efficacy of instructional modality. A mixed-methods design allowed data triangulation, securing ample evidence to warrant claims. While triangulating this quantity of data was time consuming, it was necessary to qualify the qualitative data results in conjunction with the limitations and nuances revealed through qualitative data. It was valuable and informative to share preliminary findings with stakeholders. In my view, this research project greatly enhanced my competence and leadership potential by reporting from a strong evidence base. Perceived street credibility and buy-in among faculty increased through transparency and inclusiveness.

Final Thoughts

The results of this study suggest that VPS foster clinical reasoning, collaboration, and engagement. They support the theory of situated learning, providing legitimate (medical professional) peripheral (guided) participation through simulated experiences (Lave & Wenger, 1991). VPS provide deliberate practice in an alternative format from traditional instruction, providing a peer-collaborative experience best sequenced after a session verifying readiness or a worked example provided by master clinician tutors. Experts in medical cognition (Dhaliwal, 2012; Norman, 2005) agree that the single most important attribute that distinguishes an expert diagnostician from a novice is the amount of clinical experience. Novices must achieve this through a wide variety of clinical experience, and through deliberate practice.

Standardized patient simulations are a tried and true method for training medical students, but they tend to be very expensive and staff intensive. For this reason, medical schools are investing in virtual patient simulations. VPS are also useful for distance training and standardizing small group instruction. At the outset of this project, commercially-available VPS did not exist that matched the specific requirements of the SOMA curriculum with its emphasis on forward clinical reasoning, community medicine, collaboration, technology-enhanced active learning, and integrated clinical and basic science. This project explored ways to engineer VPS to fuse these elements. I hope that the results from this study will inform other simulation projects that seek to discover better methods for training medical students to collaborate well, to synthesize evidence, and to reason toward a sound diagnosis.

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APPENDIX A

FACULTY NEEDS ASSESSMENT SURVEY RESULTS

SOMA Faculty Development Needs Assessment, 2011

In addition to teaching medical knowledge, I'm trying to teach students to be able to: ____________________________

CRITICAL THINKING

- Think critically [3]
- Think inductively [2]
- Think [2]
- Think quickly/ think on their feet [2]
- Think like a physician [1]
- Think outside the box [1]
- Translate physiology and large group presentations into physician findings: history [1]

SELF-DIRECTED LEARNING

- Find knowledge on their own [2]
- Engage and love this subject/ spark, interest in the topic [2]
- Learn
- See medical education as enhancing their personal development – mind and spirit [1]
- Work to become life-long learners. [1]
- Use knowledge constructively [1]

COMMUNICATION & PROFESSIONALISM

- Communication skills [5]
- Empathy and understanding [3]
- Professional practice [1]
- Use professional conduct always [1]
- Integrity [1]

SOMA, 1.29.11 n=32 faculty. Faculty offered many comments in open-answer paragraphs. These responses were coded using open coding. The number of responses in each category appears in brackets.

APPENDIX B

UNDERGRADUATE MEDICAL SCHOOL CURRICULAR FRAMEWORKS

Undergraduate Medical School Frameworks

	Typical Program	**This Program**
Program	**2 + 2 Model**	**1 + 3 Model**
Year 1	**Basic Medical Science Curriculum** **+ Organ system Courses** @Main Campus *Anatomy, pharmacology, physiology, biochemistry, histology, pathology, and genetics*	**Integrated Curriculum** @Main Campus *Basic Medical Science knowledge is integrated with Clinical Science (Patient Care).*
Year 2	**Basic Medical Science Curriculum** @Main Campus	**Integrated Curriculum** @ Community Health Center and via distance learning
Years 3-4 Course Sequence	**Organ System Courses** Musculoskeletal, Cardiopulmonary, etc.	**Organ System Courses with Clinical Presentation Sub-Units** Cardiopulmonary: chest discomfort, palpitations
Years 3-4	**Clinical Rotations:** @ hospitals and outpatient clinics: family medicine, internal medicine, pediatrics, OB-Gyn, general surgery, psychiatry, etc.	**Clinical Rotations + CPC** @ hospitals and outpatient clinics: Rotations are aligned with certain clinical presentations. For example, “Mood Disorders” is a topic aligned to *Psychiatry*.
Clinical Reasoning Approach	Deductive	Inductive and Abductive

APPENDIX C

STUDY EXPLANATION TO STUDENT AND FACULTY

“Virtual Patient Simulations for Medical Education:

Increasing Clinical Reasoning Skills through Deliberate Practice”

Study Explanation to Students and Faculty

- As part of an ongoing study, your simulation performance data, anonymous surveys, and data collected during required school exercises may be used for educational research and the improvement of the curriculum.
- At one point in the study, you will be invited to participate in a survey about virtual patient simulations. Participation in the survey will not count toward your grade.
- The classrooms are under constant video surveillance. Video footage may be reviewed to gauge levels of engagement. Researchers will randomly select one of the case practice sessions for transcription.
- During small group case practice, researchers will video-record case practice sessions, and randomly select a few sessions for transcribing the classroom conversations. The participant comments will be de-identified.
- For the purpose of educational research, it would be very helpful to be able to share one video of classroom activities. Any such video footage would not list student or faculty names. Prior to use in any publication, selected video footage would be presented to the students and faculty pictured for their express consent. No video footage will be shared outside the research team without a signed consent form.
- In addition, still photographs may be selected from video clips. Any photographs selected for inclusion in the research report would not list student or faculty names. Prior to publication or display at education conferences, these photos would be presented to the students and faculty pictured for consent. Photographs would not be shared without a signed consent form.
- There are no foreseeable risks or discomforts to you in our institution’s sharing the aggregate, anonymous results of this educational research. Any publishable findings will be reported in aggregate format.
- For questions about this research project, please contact Lise McCoy at lmccoy@atsu.edu.

APPENDIX D

MEASURES OF FLOW EXPERIENCE AND STATE CONCENTRATION

Items from "Skills Demands Compatibility as a Determinant of Flow Experience in an Inductive Reasoning Task"

Flow Experience

1. I did not realize how time passed.

2. I enjoyed working on the tasks

3. I was completely absorbed in the activity

4. I found the tasks to be quite exciting

State Concentration

1. I was concentrating on the task without much effort needed.

2. My thoughts were wandering around (reverse coded).

3. I was fully concentrated, without needing much effort

4. My attention was completely directed on the activity.

5. I let myself be distracted by other things.

Schiefele, U., & Raabe, A. (2011). Skills demands compatibility as a determinant of flow experience in an inductive reasoning task. *Psychological Reports*, *109*(2).

APPENDIX E

PRE-POST TEST SAMPLE ITEM

Sample Pre-Post Test Question Related to Clinical Presentation: Palpitations

Your patient suddenly becomes unconscious and has a weak carotid pulse. Cardiac monitoring, supplementary oxygen, CPR and an IV have been initiated. The code cart with all the drugs and transcutaneous pacer, defibrillator, and cardioversion capabilities are immediately available. Your first action is:

Begin transcutaneous pacing.
Begin vasopressor medication.
Give medication to accelerate heart rate.
Initiate the process of electrical cardioversion.
Place patient in a Trendelenburg position.

This test item was developed by a faculty member at SOMA (2013), adapted from a test item published by RCP Advanced Life Support (2011).

APPENDIX F

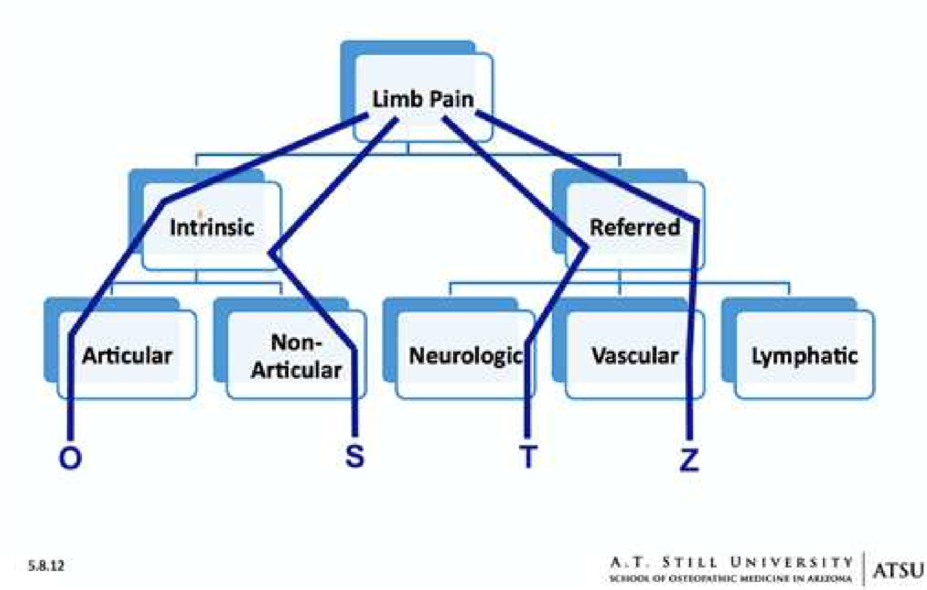
DIAGNOSTIC COMPETENCY TASK

Sample Diagnostic Competency Task

Limb Pain Competency Task 1, NMSK A Course 10.7.13

Team Code: ___________________

For the VPS case "Ariana Ochoa", what is the correct diagnostic pathway? Circle your answer at bottom left.



A. Pathway Omega - O

B. Pathway Sigma - S

C. Pathway Theta - T

D. Pathway Zeta – Z

APPENDIX G

EXIT SURVEY

A. Exit Survey, Field Test Version (Spring, 2013.)

Dear Students,

Thank you for providing feedback regarding Decision Simulation. Responses from this survey will remain anonymous, and will be used for educational research and the improvement of the curriculum. The researchers did not place any codes on the questionnaire that could directly identify you. There are no foreseeable risks or discomforts to you in SOMA's sharing the aggregate results of this educational research. Any publishable findings will be reported in aggregate format.

Completing this questionnaire should take 10 minutes. There are no direct benefits to you for completing this questionnaire. For questions about this research project, please contact Lise McCoy, Curriculum Specialist at lmccoy@atsu.edu.

1. I agree that my survey responses may be shared in anonymous format in research publications.

- Yes.
- No.

2. What is your age range?

- 22-25
- 26-30
- 31-35
- 36-40
- 41+

3. What is your gender?

- Male
- Female

Decision Simulation Exit Survey 2013

4. INTEREST: Please rate the value of the virtual patient simulation activities in terms of interest and engagement.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. They increased my interest in clinical practice.					
2. They added variety to the learning environment.					
3. They provided relevant feedback.					
4. They provided exposure to new experiences.					

5. FLOW: Please rate the value of the virtual patient simulation activities in terms of whether you were absorbed in the task.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I did not realize how time passed.					
2. I enjoyed working on the tasks					
3. I was completely absorbed in the activity					
4. I found the tasks to be quite exciting					

6. CRITICAL THINKING. Please rate the critical thinking aspects of the virtual patient simulation activities.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. They provided practice with schemes used in inductive reasoning.					
2. They increased evidence sorting abilities.					
3. They helped me review for exams.					
4. They integrated theory with practice.					

B. Exit Survey, Final Implementation Version (Main Study, Fall, 2013)

Fall 2013 VPS Exit Survey

Dear Students,

Thank you for providing feedback regarding Decision Simulation virtual patient simulations. Responses from this survey will remain anonymous, and will be used for educational research and the improvement of the curriculum. The researchers did not place any codes on the questionnaire that could directly identify you. There are no foreseeable risks or discomforts to you in SOMA's sharing the aggregate results of this educational research. Any publishable findings will be reported in aggregate format.

Completing this questionnaire should take 10 minutes. There are no direct benefits to you for completing this questionnaire. For questions about this research project, please contact Lise McCoy, Assistant Director of Faculty Development, at lmccoy@atsu.edu.

1. I agree that my survey responses may be shared in anonymous format in research publications.

- Yes.
- No.

2. What is your age range?

- 20-25
- 26-30
- 31-35
- 36-40
- 41+

3. What is your gender?

- Male
- Female

4. Please indicate your learning preference in terms of echo-360.

- a) I always rely on Echo360 for lecture content instead of attending lectures.
- b) I mostly rely on Echo360 for lecture content and sometimes attend lectures.
- c) I sometimes rely on Echo360 for lecture content in addition to attending most lectures.
- d) I rarely rely on Echo360 for lecture content since I regularly attend lectures.

Other (please specify)

5. INTEREST: Please rate the value of the virtual patient simulation activities in terms of interest and relevance.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. They increased my interest in clinical practice.					
2. They added variety to the learning environment.					
3. They provided relevant feedback.					
4. They provided exposure to new experiences.					

6. FLOW: Please rate the value of the virtual patient simulation activities in terms of whether you were absorbed in the task.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I did not realize how time passed.					
I enjoyed working on the tasks.					
I was completely absorbed in the activity.					
I found the tasks to be quite exciting.					

7. CLINICAL DECISION MAKING. Please rate the critical thinking aspects of the virtual patient simulation activities.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. They provided practice with schemes and inductive reasoning.					
2. They increased my evidence sorting abilities.					
3. They helped me review for exams.					
4. They integrated theory with practice.					
5. During VPS activities, I made decisions about the sequence of the patient encounter.					
6. During VPS activities, I gathered evidence from physical examinations to make clinical decisions.					
7. During VPS activities, I synthesized evidence to prioritize lab and imaging investigations.					
8. During VPS activities, I applied pertinent evidence at each decision point to reason toward a ballpark diagnosis.					

8. COLLABORATION. Please rate the social-collaborative aspects of the virtual patient simulation activities.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Brain-storming with fellow medical students was helpful.	○	○	○	○	○
2. Team discussion clarified concepts.	○	○	○	○	○
3. Group decision making was useful.	○	○	○	○	○
4. Working in a small team of 3 allowed better participation than working in a group of 10.	○	○	○	○	○
5. I communicated in a professional manner using respectful language.	○	○	○	○	○
6. I encouraged other members on the team to express their opinions.	○	○	○	○	○
7. Other group members communicated respectfully with me.	○	○	○	○	○
8. I put in a lot of effort.	○	○	○	○	○

9. How can we improve these activities?

APPENDIX H

BETA TRIALS PRIOR TO THE CURRENT STUDY

Beta Trials Conducted in 2012 Prior to the Current Study

Research Questions

To refine the validity and reliability of our simulations to prepare for the main study, between August and October 30, 2012, the TEAL team conducted four pre-trials of the new VP simulations. These trials were conducted with as much fidelity as was possible in the midst of busy, active classrooms at the medical school. Following a design based research approach (Barab & Squire, 2004), data were collected in the complex natural environment (small group breakout rooms) for the express purpose of innovation refinement. These beta trials sought answers to two main research questions:

1. What are student and faculty impressions regarding Decision Simulations 2012?
2. Which environments and student groupings are most effective during a Decision Sim session?
    a. Which type of classroom is conducive?
    b. Which student grouping is most conducive?
    c. What happens when the tutor controls the session?
    d. How well do students work in teams?
    e. Do students access resources during the virtual patient simulations?

Participants and Setting

Participants were 108 first-year students, six small group tutors, and four faculty Clinical Presentation Curriculum instruction experts. Trials took place on the medical school campus. This beta trial pre-study was institutionally exempted and employed a designed based, mixed methods research design—with the goal of refining the innovation. In collaboration with the TEAL team, I led the research effort, drafted data collection tools and analyzed the data, but did not provide ratings as an observer.

Methods

The TEAL team piloted six 25-minute DS case simulations with first year students during three consecutive courses. These simulation modules aligned to medical curricular content being taught in the large group lectures. For example, first-year students solved cases of pediatric fever and adult sore throat for the Foundations of Health (FOH) course, and cases. The sequence and topic content the beta trials is as follows:

The Sequence and Topic Content Areas of Beta Trials, 2012				
Trial	FOH Trial 1 August	NMSK A Trial 2 September	NMSK B Trial 3 October	NMSK B Trial 4 October
Clinical Presentation	Sore Throat	Pediatric Fever	Limb Pain	Seizure
Setting	Group size:10 Tutor leads Small Room 60 minutes	Group size: 3 Students lead Tutor- near Large Group Room 30 minutes	Group size: 10 Students lead Tutors silent Small Room 25 minutes	Group size: 3* Students lead Tutor- observe from outside on headset Small Room 25 minutes *Several dyads in one room
Data Collection	Exit Surveys from Students & Tutors	Exit Surveys from Students & Tutors	Exit Surveys from Students & Tutors	Observations from Tutors
	The students and faculty expressed that groups of ten students were too large. Cases were too long.	The students enjoyed working in groups of three but stated that they preferred small group classrooms. Students appreciated having the tutors float around the room.	The students and faculty felt these groups were too large. Some students expressed that they missed the input of tutors.	The students enjoyed working in groups of three. They did not request help from tutors. This length of simulation seemed satisfactory.

Figure H1: The Sequence and Topic Content Areas of Beta Trials, 2012.

* It was not possible, due to the number of tutors, to have only three students in one breakout room. An interesting effect was that when there were two or more student groups in one small room, a few students complained that they wanted to problem solve on their own rather than hear their peers' solutions. Faculty observing the students noted that between the small work-pods there was inter-team collaboration on answering questions.

Data Collection Instruments

The TEAL team decided to keep the survey instruments and faculty observation protocols extremely simple in an effort to be less intrusive and taxing for students and faculty. In depth preparation for each cycle of research involved the consideration and consensus of about 10 TEAL team members. Students completed simulations in small groups, and then filled out brief individual, anonymous exit surveys. Faculty tutors observed student participation and engagement, scripting notes on observation protocols. During this time period, I also interviewed four faculty experts about their opinions regarding instructional approaches and formative and summative assessments. During each trial, 90 or more first-year students submitted anonymous exit surveys designed with Likert rating scales.

Data Analysis

Data analysis included compiling quantitative and qualitative de-identified data from the exit surveys and observation protocols. To triangulate data, faculty exit survey and observation notes corroborated student exit survey responses. The narrative data rendered specific themes. After each trial, the TEAL team met to review the data, debriefed on how best to improve the next edition, and then considered which research questions to answer for the subsequent trial. I distributed the results of the trials back to the course directors. Between each trial, the TEAL team modified and optimized the simulation model.

Student and Faculty Impressions of VPS Exercises

For the Beta Trials, the first research question was as follows: 'What are student and faculty impressions regarding Decision Simulations 2012?' The preliminary data collected in these pre-trials indicated that both medical students and faculty felt that the simulations were engaging and that they practiced critical thinking skills.

The Role of the Tutor and Student Self Direction

One of the themes that emerged from the Beta Trial data was the role of the tutor. Quantitative student data indicated that students felt DS were better than the traditional PPT-format cases, but provided qualitative comments that suggest more in depth research is warranted about how they feel about having a tutor close during the sessions as a resource. VPS faculty authors argued that the advantage of the VPS educational approach was that tutors did not need to prepare and should be absent from sessions to allow students freedom of choice. It emerged after several sessions that students were interested in exploring the wrong answers. For each option they click, students receive feedback on the decision. In review of this phenomenon, the TEAL team inferred that there is experience value in students checking the feedback for incorrect responses, and by exploring a short way down "incorrect decision paths" in the case.

User Interface

Each trial collected feedback about the user interface: the game mechanics, technological glitches, obstacles to learning, and the embedded audio and video clips. By the third trial, students reported that the simulations were relatively technologically error-free. In terms of the user interface, students indicated that they appreciated a more streamlined approach with fewer lines of text, the inclusion of rich media, and requested that the text be proofread.

Optimal Student Groupings and Learning Environment

The second research question during beta trials was: Which environments and student groupings are most effective during a DS session? To answer this question, the TEAL team tested the new VPS in four different setting configurations, summarized in Figure H1. From the trials, I learned that student groups of three or four rendered more complete member participation than groups of 10. From faculty observations, data indicated that in general, no one student takes control, and there were balanced team dynamics. Some students mentioned that they preferred break-out rooms to the large study hall for working in teams. Others mentioned that in a large study hall, they enjoyed the proximity of floating faculty. Many students requested access to the simulations for individual practice. This access was afforded to them post hoc.

Summary of Beta Trial Findings

Figure H2 provides a summary of key mini studies conducted during the Beta Trials of fall, 2012. These studies provided groundwork for the proposed study. The proposed study will confirm some of these findings and then expand toward the horizon of the learning effects of the simulations.

A Summary of Findings from Beta Iterative Trials, Fall 2012	
Data Collection Tools	**Findings**
First Year Student Exit Surveys from 4 Decision Simulation Trials, Fall 2012 (n=108)	• Students contributed during the simulation. • Students indicated that the VPS were effective for deliberate practice with schemes. • VPS required critical thinking and problem solving. • Students were absorbed in the activities and they were engaging.
Four Interviews with CPC experts. Fall, 2012.	• Students should be able to explain their reasoning at every branch point of the scheme.
Faculty Observations of Decision Simulation Session. Fall, 2012.	• Students participate actively VPS together in groups of 3-4. • Students take charge of their learning environment, accessing notes and other group members to complete their VPS exercises.
Observation Analysis. Fall, 2012.	• VPS deliver several learning affordances distinct from the standardized patient format.

Figure H2: A summary of findings from beta trials, fall 2012.

During these beta trials, I noted several intriguing unexpected phenomena. 1) A few students appeared to be paying attention to the cost of lab investigations. 2) A few students displayed commitment and engagement by setting themselves a challenge and replaying the session for focused skill practice. 3) VPS have the potential to address learning needs in a multi-level classroom: students ready for higher level skills move through them swiftly, while other students move through them slowly. 4) VPS may be constructed to reflect the target competencies and service values of SOMA students and faculty whose stated mission it is to serve in medically underserved areas. 5) Simulations provide a “wisdom table” (Hunter, 2011) a forum in which students explore the consequentiality of their values and decisions.

APPENDIX I

ADVANTAGES OF DECISION SIMULATIONS

Advantages of Decision Simulations

Case Sharing Among Institutions

Although VPS have been found to be useful to students to provide standardized lessons, due to the high cost of faculty time required for developing interactive patient case simulations, the medical community is trying to create common libraries (Ellaway et al., 2008). Since they are housed online on a common server accessible to all medical schools using Decision Simulation, this platform has case-sharing functionalities. Faculty may designate their cases to be shared among subscribing institutions. The implication for our study is the new patient cases, they have the potential to be shared with a larger network of medical schools, and they reside protected and properly tagged with metadata including competencies, key authors, and course designation inside a reusable library of established, vetted and refined cases.

Cost Effectiveness

As reported by a group of VPS researchers from Harvard Medical School, VPS are expensive and time consuming to develop. For example, creating one VPS can take upwards of 60 hours of faculty time and $50,000 dollars (Feldman, Barnett, Link, Coleman, Lowe & O'Rourke, 2006). Transferring existing complete cases to VPS at this medical school required only 20 hours of faculty time per module (as reported by local faculty). The implication for this study is that creating a relatively streamlined VP Simulation model that could eventually be cost saving for several reasons. First, students can complete the cases on their own, and since the answers to questions are provided as feedback within the case modules, it might reduce the case preparation load for multiple faculty tutors. Second, cases can be filed and organized in a central location and be reused year to year. In this fashion, they accumulate into a sustainable, enduring enrichment library for online case practice during the years when students are distributed to individual learning sites. Finally, they have the potential to act as faculty development or continued medical education for tutors new to the CPC or to the clinical presentation being discussed. For example, if one tutor is a pediatrician, he or she might not have fluency with an internal medicine case, and vice-versa, and he or she can play through the case prior to small group practice. In their literature review of VPS, Cook and Triola indicate that is important to review the relative advantages of VPS over other types of simulations (2009).

APPENDIX J

DEFINITIONS

AACOM	American Association of Colleges of Osteopathic Medicine
Abduction	A cyclical process of generating possible explanations (i.e., identification of a set of hypotheses that are able to account for the clinical case on the basis of the available data) and testing those explanations (i.e., evaluation of each generated hypothesis on the basis of its expected consequences) (Patel, et al., 2004).
Basic Medical Science	A term that usually refers to the initial two years of a medical school's program. However, in some schools, this may entail more or less than two years (Wojtczak, 2002). Basic medical science comprises physiology, biochemistry, pathology, hematology, and anatomy, and pharmacology while clinical science comprises medical approaches, diagnostic procedures, laboratory tests, and patient examinations, and treatment of patients.
Branching Case	A tree-like structure of available pathways which allows students to select the best option at each stage of the case (Ellaway et al., 2008, p.171).
Clinical presentation scheme	Using a flow chart as a map for a patient case, the medical trainee processes information and reasons down one or more paths of the scheme, moving from the complaint to a diagnosis, with consideration given to the patient history, physical condition, lab test results, as well as principles of basic science (physiology, hematology, anatomy) to move inductively toward increased specificity and a diagnosis (Schwartz et al., 2012).
Clinical settings	Community clinics, hospitals, physician offices.
Clinical vignettes	Scenarios, when viewed on a computer screen, are known as virtual patient (VP) cases (Poulton et al., 2009).
Community of Practice (CoP)	A Community of Practice (CoP) conducts projects and designs tools, creates and stores knowledge in a website, engages in practice as a voluntary activity, discusses common topics outside of meetings (Wenger, 1998).
Constructivism	Constructivists do not view the learner as simply reacting to external stimuli, but celebrate active learning and participation in group activities learners acquire knowledge through interaction with the environment and others. (Kivinen & Ristela, 2003)
CPC Schemes	Inductive trees' or 'road maps' to recreate the major divisions (or chunks) used by expert clinicians for both storage of knowledge in memory and its retrieval for solving problems (Coderre et al., 2003).
Crucial tests	These tests may be based on an evaluation of symptoms, signs, or results of investigations, singly or in any combination. The literature terms this “eliminative induction” (Forber, 2011).
DecisionSim™	A tool for authoring VPS cases by Decision Simulation.
Design Based Research	An approach to research useful for development of education innovation projects, that is pragmatic, grounded, interactive, integrative, and contextual (Wang & Hannefin, 2005).
Evidence Centered Design (ECD)	ECD employs the use of Bayesian networks toward accurate inferences of competency states (Earman, 1992).
Free rider effect	The passive participation of certain learners within a group who reap the rewards of group effort (Piezon & Donaldson, 2005).
HRSA	Health Resources Services Administration

Hypothetical-deductive reasoning.	“Backward” thinking, reasoning from hypothesis to evidence (Patel et al., 2004).
Illness scripts	Memories or prototypes for solving different case presentations in later years (Charlin et al., 2007).
Implementation dip	There is often a six month period of negative gains in the first phase of implementing an innovation (Fullan, 2011).
Induction	Forward thinking: reasoning from evidence to hypothesis (Patel et al., 2004).
Inductive reasoning	“Forward thinking”, or reasoning from prior experience or evidence to a hypothesis (Patel et al., 2004).
Labyrinth™	A virtual simulation platform, precursor to Decision Simulation.
Legitimate peripheral participation	Engaging in a limited scope of participation within the professional community of physicians (Lave & Wenger, 1991)
Linear case	A case which unfolds along one line, which results in tutors guiding the student down the key decision pathway (Poulton et al., 2009).
Mannequin simulations	…”Mannequins constructed to respond realistically to actions, allowing examinees to reason through a clinical problem without risk to a real patient (Wojtczak, 2002)
Medical cognition	The study of cognitive processes, such as perception, comprehension, decision-making, and problem solving in medical practice itself or in tasks representative of medical practice” (Patel, Arocha, & Zhang, 2004, p.2).
Modified Delphi process	(Custer, Scarcella, & Stewart, 1999)
OMSI	Year 1 osteopathic medical students.
OSCE	Objective Clinical Skills Exams: A standardized means to assess physical examination and history-taking skills, communication skills with patients and family members, breadth and depth of knowledge, ability to summarize and document findings, and ability to make a differential diagnosis or plan treatment (Wojtczak, 2002).
Outcome	All possible demonstrable results that stem from casual factors or activities. (Wojtczak, 2002).
Pattern matching	A process whereby the physician can diagnose by matching symptoms and conditions of the current patient to prior cases in memory (Coderre et al, 2003).
Perspectival frame	A common frame of reference among two or more individuals (Van de Sand & Greeno, 2012).
Pertinent negative	The relevant patient data for each decision in the case --the patient does not display this symptom (TEAL team, 2013).
Pertinent positive	The relevant patient data for each decision in the case (the patient displays this symptom) (TEAL team, 2013).

Propositions	When subjects identified key phrases called “propositions” that linked categories of knowledge, this provided evidence for scheme induction, “categorization” or “inductive reasoning”. (Coderre et al., 2003)
Recursiveness	Recursiveness describes a process in which the solution to the problem depends on the solutions of prior problems.
Scaffolding	An instructional strategy: when students cannot complete a task or project alone, scaffolding is the assistance they receive from a mentor, tutor, or peer (Sherin, Reiser, and Edelsen, 2004).
Schemata	Mental maps, or routines for solving the problems (Harasym, Tsai, & Hemmati, 2008)
Self-directed learning	A form of education that involves the individual learner's initiative to identify and act on his or her learning needs (with or without assistance), taking increased responsibility for his or her own learning. (Wojtczak, 2002)
Social loafing	The tendency of certain students to expend less effort during group work even when they might work harder alone (Dillenbourg & Hong, 2008).
SOMA	School of Osteopathic Medicine in Arizona (SOMA).
Standardized patient simulations	Simulated patients are healthy persons who have been trained to reliably reproduce the history and/or physical findings of typical clinical cases. Sometimes actors are used to accomplish this goal but more often, health care providers are used. Use of an SP is designed to assess students' clinical skills while making the examination as objective as possible. Note that teaching an SP to simulate a new clinical problem takes eight to ten hours (Wojtczak, 2002).
Stealth assessment	Assessment features which are embedded in games (Shute, 2011).
Summative test	*Summative individual evaluations* measure whether specific objectives were accomplished by an individual in order to place a value on the performance of that individual. It may certify competency or lack of competency in performance in a particular area (Wojtczak, 2002).
Triangulation	A method of assessment that is required when validity cannot be achieved with the use of a single assessment tool. If multiple testing methods are used to evaluate a single competence, one can be more certain that the competency has been appropriately assessed. (Wojtczak, 2002)
UGME	Undergraduate medical education; medical school
Virtual Patient Simulations (VPS)	Computer modules or games with simulated patients in virtual environments. Providing students with VPS to rehearse patient case scenarios before they encounter live patients is a safe approach to medical education (Ziv, Wolpe, Small, & Glick, 2006).
Wisdom table	A forum in which students explore the consequentiality of their values and decisions. (Hunter, 2011).
Zone of proximal development	The gap between what a student currently understands and the target concept, which scaffolding up to new skills gradually, in proximity to the skills already in place (Vygotsky, 1978; Aufschnaiter, 2003).

APPENDIX K

PERMISSION TO CONDUCT RESEARCH: SOMA

-Advice about running specific statistical tests from Curt Bay or a statistician.

☐ **The audience(s) for your findings.**

Unknown, but these are the potential audiences for the findings:

A) To SOMA administration.

B) To SOMA faculty or students – if requested.

C) At the 1st International Clinical Presentation Curriculum Conference, February 2014

D) In the form of a shorter journal article to be published in Medical Teacher, Journal of Medical Simulations, or similar publication

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PERMISSION FORM

I give permission for Lise McCoy to conduct this dissertation research for her doctoral degree.

3/4/13

Frederic N. Schwartz, D.O. Simulation Game Team Chair **Date**

APPENDIX L

INSTITUTIONAL REVIEW BOARD APPROVAL

ASU Knowledge Enterprise Development

Office of Research Integrity and Assurance

To:	Keith Wetzel FAB
From:	Mark Roosa, Chair Soc Beh IRB
Date:	05/31/2013
Committee Action:	**Exemption Granted**
IRB Action Date:	05/31/2013
IRB Protocol #:	1305009198
Study Title:	Virtual Patient Simulations for Medical Education: Increasing Clinical Reasoning Skills through Del

Dianne DeNardo Digitally signed by Dianne DeNardo DN: cn=Dianne DeNardo, o=ASU, ou=ORIA, email=Dianne.DeNardo@asu.edu, c=US Date: 2013.05.31 11:03:57 -07'00'

The above-referenced protocol is considered exempt after review by the Institutional Review Board pursuant to Federal regulations, 45 CFR Part 46.101(b)(1) (2) .

This part of the federal regulations requires that the information be recorded by investigators in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects. It is necessary that the information obtained not be such that if disclosed outside the research, it could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

Institutional Review Board
A. T. Still University
EXEMPT REQUEST APPROVAL

DATE:	April 29, 2013
TO:	Lise McCoy, MTESL School of Osteopathic Medicine in Arizona
FROM:	ATSU, Arizona IRB Committee
SUBJECT:	Exemption from IRB Review, IRB Application #2013-068

Your application to the ATSU, Arizona IRB regarding "Virtual Patient Simulations for Medical Education: Increasing Clinical Reasoning Skills with Deliberate Practice," IRB Application #2013-068, proposes to collect no data associated directly or through identifiers linked to participants. It is, therefore, exempt from IRB review.

You may now proceed with data collection. If your research or supporting documents deviates from materials submitted in your application to the ATSU, Arizona IRB requesting exemption, you must seek approval or exemption from the ATSU, Arizona IRB prior to any work involving human subjects being undertaken. Otherwise, no further reporting to the ATSU, Arizona IRB is required. Please keep this letter for your study files to verify IRB review.

APPENDIX M

INSTRUCTIONS GIVEN TO STUDENTS BEFORE VPS EXERCISE

Instructions to Students for VPS Activities

1. Today's case practice session is part of an ongoing study this term regarding virtual patient simulations. This study was approved by the ATSU IRB in April, 2013.
2. Today you will complete a Decision Sim case in a team of 3-4 students.
3. During this simulation, you will assume the leadership role in taking care of this patient.
4. One student in the team of 3-4 will log into DS to open the case.
5. Collaboration is important during this case. Please ensure that everyone contributes to the decision making.
6. Please ensure that everyone can see the screen.
7. Use only one laptop for your team of 3-4.
8. Try to complete the exercise by discussing the case among your team members.
9. Your facilitator wants you to take charge.
10. You may ask your facilitator questions.
11. This exercise should take no longer than 20 minutes.
12. At the end of the exercise your team will complete a "Diagnostic Competency Task."
13. This Competency Task exercise should take no longer than 5 minutes.
14. Your performance on this task will not affect your grade.
15. Please negotiate with your team members regarding the answer to the team competency task question quietly.
16. Work in a team to mark the correct answer quietly.
17. Please do not ask your facilitator for assistance with this task.
18. Create a 4-letter acronym code for your team Ex: Team FAST.
19. Mark your team's ID code on the task form.
20. Indicate your facilitator's name on the task form.
21. Submit the Competency Task in the envelope provided marked "Competency Task".
22. This envelope should be returned to the first-year coordinator.
23. As usual, sessions in the small group rooms will be video recorded.
24. Researchers will randomly select one of the case practice sessions for transcription.
25. Please do not ask your facilitator for assistance with this task.
26. Create a 4-letter acronym code for your team Ex: Team FAST.
27. Mark your team's ID code on the task form.
28. Indicate your facilitator's name on the task form.
29. Submit the Competency Task in the envelope provided marked "Competency Task".
30. This envelope should be returned to the first-year coordinator.
31. As usual, sessions in the small group rooms will be video recorded.
32. Researchers will randomly select one of the case practice sessions for transcription.

APPENDIX N

VP SIM TUTOR INSTRUCTIONS

Instructions to Tutors for VPS Activities

1. Today the students will be completing a 20 minute virtual patient simulation case.
2. During these simulation exercises, your role is “Guide on the Side”.
3. Please feel free to circulate among the students.
4. Please only answer questions as asked, but do not give the answer. Direct them to information which will help them make the decision.
5. Please be brief, and allow the students to move through.
6. Students are allowed to take notes during the case.
7. It is ok if students do not complete the entire case.
8. At the end of the session, student teams will complete a “Diagnotic Competency Task”.
9. Please do not help them complete the task.
10. Students should place the completed task worksheet in the envelope provided.
11. This envelope is extremely important and should be returned to the Year 1 Coordinator.
12. After the competency tasks have been submitted, please lead a 10-minute debrief regarding the case using the discussion questions provided, but do not allow students to change their answers on the competency task.
13. In the comments section below, you are invited to reflect on how to improve this sim.

APPENDIX O

STUDENT INSTRUCTIONS PRE-TEST AND POST-TEST

Student instructions Pre- Test

1. As part of normal, required class activities, you will complete a 20-item pre-test.
2. You may not know all the answers to the pre-test. Please do not be concerned.
3. You will be provided with 15 minutes to complete this test via ExamSoft.
4. This test will not affect your grade.
5. However, please try to do your best, as faculty will try to assess learning gains from this test.
6. The data from this assessment will be aggregated and used for improving instruction.
7. After the pre-test you will continue your normally scheduled case practice.

Student instructions Post- Test

1. As part of normal, required case practice activities, you will complete a 20-item post-test.
2. You will be provided with 15 minutes to complete this test via ExamSoft.
3. This test will not affect your grade.
4. However, please try to do your best, as faculty will try to assess learning gains from this test.
5. Data from this assessment will be aggregated and used for improving instruction.

APPENDIX P

SAMPLE STUDENT CLINICAL DISCUSSIONS

Student Clinical Discussions by theme and by AOA Competency		
Code	VPS Discussion Example	AOA Competency
Clinical Presentation (CP) Scheme	S3: Genetic vs. idiopathic. Yeah, we need to know that. His family history is insignificant, but I don't know if that means it is not genetic.	I4a Identify the patient's chief complaints… III.2.b Generate and test multiple hypotheses during the course of the medical interview and physical examination.
Order of Investigations	F: History first? Maybe the HI? M1: Select the scheme on treatment plan or [history of the present illness] HPI. M1: Probably HPI. Let's elicit the seven characteristics.	II1j. Perform the patient encounter as appropriate for the situation.
Patient History	[Reviewing back pain history] S2: Acute. [Pain] S1: He fell. Wallet…. S2: Says it's completely new. S3:.Not like electrical static shooting. S2: It's not like it's electrical. S1: It gets worse when he moves around. S3: Muscle strain, or something.	I.3.1.b Take an accurate history by communicating effectively
Analyze Patient Data	[Reviewing patient data-seizure] …He did have a PERLA on his vision. He's in the right age range for the myoclonic juvenile seizure. He lost consciousness. He had been drinking, which was a risk factor.	III.2a Synthesize into an organized presentation all information gathered as part of the patient encounter, including history and physical findings, chart review, laboratory and diagnostic findings, epidemiological data, psychosocial, cultural, and religious factors, patient age, risk factors, and patient concerns.
Basic Science Concepts/ Define a term or concept	S2: Decreases the vesicle. S1: Protein? S1: SVA-2 S2: SVA-2.	II.1.Articulate basic biomedical science and epidemiological and clinical science principles related to patient presentation…
Clinical Pearls/ Red Flags/ Patient Exam	[Reading Clinical Pearls] S3: These are cool. S2: A tic. I think we all have those. S3: I have tics in my eye all the time. Cyclical vomiting sounds horrible.	III.3a. Perform a clinically appropriate standard physical examination, including evaluation of each of the body areas

Lab & Image Choice	[Back Pain Lab Tests] S3: Do you think we need to order any tests? S2: We aren't going to do orthopedic surgery if it's neurologic. S3: I don't think it's a disc herniation. If it was, we have to do an MRI. (session 2)	14i. Prioritize diagnostic tests based on sensitivity, specificity, and cost-effectiveness.
Cost of procedures	[Back Pain Imaging] S2: I would do imaging as opposed to lab work. S1: For sure. Yeah. But the MRI is not going to show us. He said it is neurological. So maybe an MRI would show us more? S2: I just think an MRI would cost more.	14i. Prioritize diagnostic tests based on sensitivity, specificity, and cost-effectiveness.
Deep discussion / Debate	S2: An x-ray doesn't tell us anything. S1: Ultrasound, maybe! S2: I don't know what we're looking for now. S3: Do X-ray AND ultrasound *[laughing].* S1: Are they saying they want to order an MRI on this guy? S2: That's what I thought. S1: Go back. S3: Let's just try it? Do you want to do it? Good. Why would you do an MRI?!	IV.4.a. Collaborate with other health care professionals in the care of the patient demonstrating effective personal skills and interpersonal dynamics.
Develop theory or diagnosis	S1: So wait, when Robert, you notice that the left leg is somewhat rotated at the hip. So this is piriformis, right? S2: Pain, you rotate at the left leg. S1: Piriformis is irritated. S2: Could be impinging on the nerve. S1: It's kind of a weird dull pain. It's so sharp. S2: That's true. S3: So when you pull on those muscles, right? Man, it's almost, like, neurological. S2: I think we should do a neurological exam. S1: Yeah, let's do it. Straight leg race is positive. That's indicative of disc herniation.	1.4.b Identify key history and physical examination findings pertinent to the differential diagnosis.
Muddy Point	S2 Well like an absent seizure is generalized. You don't remember it? S3 I don't know.	IV.4.b Communicate a coherent story of illness, diagnosis, and treatment.
Frustration with clinical decision making	S1 How about a choice? S3: I don't know! S1: Make a decision. S3: Not epilepsy S2: We have no reason to think it is epilepsy. S1: Not hypoglycemic—seizure.	III.4.i Recognize personal limitations in training and ability; seek consultation and specialty referral as appropriate.

Objectives	S1: Disc herniation. S2: The crossed SLR is negative. S3: This test is really specific for… S2: Posterior Lower leg. So it would be…. S1: Is it L2? S3: Lateral. S2: [Demonstrating on himself] This will be the tibial nerve.	
Anatomy/ Physiology/ OPP	S1: Hey! Yo! [Feedback received]. S2: [Laughing]. S1: Torsion. Bilaterally… S2: So it's sciatic. S3: Hm [agree]. So the left sciatic notch….tender firm sausage like mass… S3: So it's a big muscle spasm. Probably a bruise. Maybe a deep bruise S1: Distal vertebrae. S3: Oh, between the sciatic… S1: Which is exactly the insertion of the piriformis, because the piriformis [muscle] inserts on the lateral. ..trochanter…It's all….	I.5b Differentiate and perform specific manipulative techniques and assess their outcomes, e.g., high velocity-low amplitude (HVLA), articulatory, muscle energy, soft tissue, strain-counterstrain, myofascial release, lymphatic balanced ligamentous, ligamentous articular strain, facilitated positional release, Still, visceral, and cranial techniques.
Treatments	[Epilepsy Treatment] S1: Then, Volpomax…We didn't talk about it, but we can talk about the way it works, but it works in a similar way to valproic acid S2: So the treatment is life-long. S3: Yep. S1: Sorry. I'm trying to help us study. S2: It helps us a lot!	

APPENDIX Q

PRE- AND POST-TEST STATISTICS

Table Q1

Pre- and Post-test Item Distribution, Main Study, Session I N=107

Session I		**Pre-test**		**Post-test**	
		Statistic	SD	Statistic	SD
Mean (in percent)		44.96%	1.29	55.29%	1.14
95% Confidence Interval for Mean	Lower Bound	42.40		53.03	
	Upper Bound	47.51		57.55	
5% Trimmed Mean		44.76		55.53	
Median		47.37		57.90	
Variance		177.85		138.70	
Std. Deviation		13.37		11.78	
Minimum		15.79		26.32	
Maximum		78.95		78.95	
Range		63.16		52.63	
Interquartile Range		15.79		15.79	
Skewness		0.13	0.23	-0.28	0.23
Kurtosis		-0.067	0.46	-0.20	0.46

Table Q2

Pre- and Post-test Item Distribution, Main Study, Session II, N=107

Session II		**Pre-test**		**Post-test**	
		Statistic	SD	Statistic	SD
Mean (in Percent)		64.95%	1.16	78.74%	0.97
95% Confidence Interval for Mean	Lower Bound	62.66		76.81	
	Upper Bound	67.25		80.66	
5% Trimmed Mean		64.98		78.93	
Median		65		80	
Variance		143.16		100.99	
Std. Deviation		11.97		10.05	
Minimum		35		55	
Maximum		95		100	
Range		60		45	
Interquartile Range		10		15	
Skewness		-0.01	0.23	-0.28	0.23
Kurtosis		0.76	0.46	-0.55	0.46

Table Q3

Pre- and Post-test Item Statistics, Main Study, Session I

Session I	Pre-test		Post-test	
Item #	Point Biserial	P-value (%)	Point Biserial	P-value (%)
1	0.45	85.71	0.29	96.15
2	0.18	50.48	0.25	52.88
3	0.32	48.57	0.36	59.62
4	0.29	30.48	0.29	33.65
5	0.37	73.33	0.27	82.69
6*	0.06	00.95	-0.03	09.62
7	0.04	22.86	0.00	09.62
8	0.31	40.95	0.26	54.81
9	0.39	66.19	0.53	63.46
10	0.41	45.71	0.38	74.04
11	0.01	11.43	-0.17	05.77
12*	-0.01	01.90	0.00	00.00
13	0.27	73.33	0.35	66.35
14	0.34	46.67	0.39	71.15
15	0.24	49.52	0.14	62.50
16	0.36	24.76	0.44	45.19
17	0.36	44.76	0.40	54.81
18	0.23	27.62	0.24	40.38
19	0.42	40.95	0.20	89.42
20	0.36	65.71	0.28	85.58
Analysis		**Pre-test**		**Post-test**
KR20		0.38		0.28
SD		2.51		2.21
Mean Raw Score		8.41		10.48
Med		8.00		11.00
Min		3.00		5.00
Max		15.00		15.00
Total		19.00		19.00
Participants		105		105

* This item was omitted in student performance scores due to lack of image.

Table Q4

Pre- and Post-test Item Statistics, Main Study, Session II

Session II	**Pre-test**		**Post-test**	
Item #	Point Biserial	P-value (%)	Point Biserial	P-value (%)
1	0.26	86.54	0.16	93.27
2	0.45	39.42	0.43	59.62
3	0.26	83.65	0.19	98.08
4	0.27	66.35	0.49	84.62
5	0.18	85.58	0.28	85.58
6	0.36	61.54	0.38	62.50
7	0.00	100.00	0.00	100.00
8	0.41	53.85	0.24	95.19
9	0.21	83.65	0.12	88.46
10	0.24	33.65	0.19	68.27
11	0.27	66.35	0.29	62.50
12	0.17	33.65	0.10	87.50
13	0.40	21.15	0.32	47.12
14	0.21	82.69	0.35	38.46
15	0.43	27.88	0.31	99.04
16	0.10	85.58	0.04	45.19
17	0.49	69.23	0.30	54.81
18	0.23	64.42	0.32	40.38
19	0.19	72.12	0.22	86.54
20	0.37	80.77	0.38	89.42
Analysis	**Pre-test**		**Post-test**	
KR20	0.39		0.33	
SD	2.43		2.02	
Mean Raw Score	12.98		15.78	
Med	13.00		16.00	
Min	7.00		11.00	
Max	19.00		20.00	
Total	20.00		20.00	
Participants	104		104	

Item Analysis

Since pre- and post-tests were taken via Exam Soft, assessment staff used Exam Soft to generate test item statistics reported in Tables Q3 and Q4. Participant n’s reported in Tables Q3 and Q4 are slightly lower than the total test performance N of 107 reported in Tables Q1 and Q2 due to the fact that a few students with computer issues submitted assessments in paper format. The item analyses in Tables Q3 and Q4 do not include test results from these paper forms.

Item Discrimination Index (Point-biserial Correlation Coefficient). The item point-biserial indicates the item quality. An item is considered to be discriminating if the higher performing students tend to answer the item correctly while the lower performing students tend to respond incorrectly (Wells & Wollack, 2003). The point-biserial correlation coefficient (ranging from -1.0 to +1.0) indicates the correlation between the students' overall performance on the exam and specific performance on a particular question. When the correlation is negative, it indicates a problem with the item, suggesting that the knowledgeable examinees are scoring lower than less knowledgeable examinees (Professional Testing Incorporated, 2006).

Item Difficulty Index (P-value). The Item Difficulty Index, or p-value statistic ranges from 0 to 1.0. This index indicates the proportion of participants that answered the test item correctly. The higher the p-value, the easier the item (Professional Testing Incorporated, 2006).

Kuder-Richardson Formula 20 (KR-20). The KR-20 correlation statistic indicates the reliability of the examination. The Kuder-Richardson formula calculates the item reliability (Bodner, 2013). According to Thompson (2010) a KR-20 of 0.7 is acceptable. The KR-20 values for these assessments were likely low due to the due to the brevity of the assessments (personal conversation with Ray Buss, 2.15.13).

Skewness and Kurtosis. Skewness is the measure of the symmetry of a variable's distribution around the mean. A zero value indicates balance. Kurtosis is the measure of the sharpness or 'peakedness' of the peak relative to a standard bell curve (Brown, 2011). The distributions of the assessments were relatively symmetric for the Main Study.

Test Items/ Test Content. A sample test item and discussion of test content is provided in Chapter 4. Consistent with the policies of the school, the exact exam items are archived for future use (if viable), and are not distributed.

APPENDIX R

CODE BOOK

Table R1 reports codes used in HyperRearch to code transcribed transcriptions of student/ tutor dialog, observer session observations, observer memos, and tutor feedback forms.

Table R1

Codes for Qualitative Data

Domain/ Theme	Code	Description
VPS Activity	**Code**	**The VPS case activity**
Lesson Fidelity	Implementation - per plan	Lesson was implemented with fidelity- researcher's observation note
	Quickly form groups	Students form triad groups quickly with little scaffolding.
VPS Mechanics	Write notes during case	Students take notes - voluntarily
	Discuss feedback	Students discuss choice feedback during VPS
	Discuss research study	Students ask tutor clarifying questions
	[Non] graded activity	Students mention that activity is not graded
	Scoring [system]	Students mention the scoring system
	Patient chart	Students mention the patient's chart (health record)
To Improve	Critical of VPS	Students are critical of VPS activity
	To refine	To refine or improve for next iteration
	To improve	To refine or improve for next iteration
	Tutor preparation	Comments about whether the tutor previewed the VPS case.
Classroom Environment	Classroom ambiance	Comments about the classroom energy or environment.
Task	Competency task	Students discuss the competency task.
	Discuss task	Students discuss how to complete the VPS case.
	Anxiety (task)	Students express worry or anxiety about the task.
	Complain task	Students complain about the task.
	Complete task	Students discuss completing the task.
	Confusion about task	Students express confusion about the task.
Case Content	Content	Students comment about VPS case content.
	Content misalignment	Students comment about whether case content matches what they learned in large group.
	Good learning activity	Participants say the activity is a good learning activity.
	Tutor review of content	Tutor comments regarding content

Time Constraint	Wish to continue	Students express wish to continue play past 20 minutes.
	Continue beyond time limit	Students express wish to continue play past 20 minutes.
	Discuss time limit	Students express awareness of 20 minute limit.
	Time to complete case	Comments about enough time to complete case
	Time	An awareness of how much time there is left.
Technology Issues	Log on	Students encounter issues with log on.
	Waiting to install or load	Students wait for VPS to install or load.
	Technical glitch	Technology glitch encountered,
	Technology ideas	A proposed technology solution.
Text	Screen Text	Students mention quantity of screen text
	Reading on screen	Students are reading text on screen
	Shortcut	Students express wish to take a shortcut.
	Silence while reading	Students are silent while reading
Clinical Decision	**Code**	**Clinical reasoning during VPS**
Clinical Presentation	Refers to scheme or CP	A discussion regarding the scheme flow chart or the patient's clinical presentation.
History	History	A discussion regarding patient history
	Order of investigations	A discussion regarding prioritizing the order of investigations.
Basic Science	Basic science	Concepts such as microbiology and chemistry
	OMT/Anatomy/Physiology	A discussion regarding osteopathy (bone and joints), anatomy, or physiology
	Define a term or concept	Students / professors define terms or concepts
Patient Exam	Patient exam	Discussion during the patient examination.
	Red flags	Tutors explain which symptoms and signs indicate serious conditions.
Investigations	Analyze patient data	Students analyze patient data.
	Sort evidence	Students sort evidence.
	Interpret lab or imaging	A discussion regarding interpretation of lab values or imaging such as x-ray, CT.
	Lab & Image Choice	A discussion regarding prioritization of lab values or imaging such as x-ray, CT.
	Consider cost of procedure	Students mention the cost of a clinical procedure.
Diagnosis	Develop Theory or Diagnosis	Students develop a diagnosis, beginning with a theory based on evidence.
Treatment	Patient care	A debate regarding best approach to patient care.
	Treatments	A discussion about treatment, medication, or therapy.
Post-Diagnosis Discussion	Objectives	Discussion regarding case objectives.
	Clinical Pearls	Enrichment knowledge provided by clinical expert.

Student Strategy	Doctor personae	Students assume the role of physician
	Frustration	Students express frustration.
	Make a decision	Students discuss the need to make a decision.
	Muddy Point	Students struggle with a difficult concept.
	Debate a point	Students debate a decision point.
	Deep discussion regarding decision	Students engage in an extended deep discussion
Collaboration	**Code**	**Evidence of collaboration or lack thereof**
Collaboration	Collaboration from the observer's perspective	The researcher-observer notes what appears to be collaborative behavior.
	Collaboration from the tutor's perspective	The tutor-observers note what appears to be collaborative behavior.
Encourage participation	Consider colleague viewpoint	A student indicates that he/she is considering the viewpoint of another.
	Discussion among peers	Students discuss among themselves.
	Professional	The conversation reflects a professional tone.
	Apologize	Students apologize for interrupting each other.
	Encourage a peer to contribute	A student solicits the opinion of a peer.
	Agree by saying um hum	**Students express agreement as "um hum."**
Compassion	Discuss patient care	Students express care or compassion for the patient.
Teamwork	Express team Identity or Spirit	Students congratulate the 3-person team or express solidarity.
Communication	Disrespect to peer	A student makes a joking comment unflattering to a peer.
	Interrupt	A student interrupts someone else.
	Lack of professional word choice	The conversation reflects vernacular, instead of professional level jargon.
	Non-compassion toward patient	Conversation about the patient does not reflect a compassion-centered viewpoint.
Engagement	**Code**	**Evidence of engagement or lack thereof**
General	Engagement from the observer's perspective	Researcher-observer notes behavior that indicates students are engaged.
	Engagement- from the tutor's perspective	Tutor-observers note behavior that indicates students are engaged.
Flow	Gesture	Students stretch their arms or legs to demonstrate joint movement.
	Gratitude to professor	Students express gratitude to absent professors.
	Humor	Students laugh or joke.
	Interaction	Students interact with each other.
	Enthusiasm about score	Students express excitement over a high score.
	Cheering or enthusiastic outburst	Students cheer, exclaim, or high five each other.
	Focus on activity	Observers note that students are focused.

Engagement – low	Fatigue	Observers note that students are fatigued.
	Leaning back	Students sit away, apart, or lean away from activity.
	Nervousness	Students express nervousness.
Interest	Surprise	Aspects of case are shocking.
	Interest	Students express interest in case subject matter.
	Explain	One student is explaining something to another
Relevance	Satisfaction	Students express satisfaction with competency task or case completion.
	Raise a question	A student is raising a question
Theory Building	**Code**	**Researcher memos developing theory.**
Researcher theories	My theories	Researcher comments about student struggle, utility of case notes, etc.
	Stepwise method	Theory of networked lessons.
	Number of cases per session	Notes regarding the number of cases (VPS and PPT) per tutor session (4)
	Progression of activity	Observer notes about the progression of the activities
Tutor Interactions	**Code**	**Evidence describing tutor interactions**
Tutor role	Clarify incorrect information	The tutors clarify incorrect student assumptions.
	Clarify task instructions with tutor	The students request the tutor to clarify instructions regarding the VPS activity.
	Consult the tutor	The students ask the tutor a question during the VPS.
	Discuss the research study	The tutor fields a question regarding the research study.
	Interpret lab or imaging	The tutor interprets lab values or images such as x-ray, CT, etc.
	Positive reinforcement	The tutor provides a kind comment to a student.
	Tutor asks questions	The tutor asks the entire group of 10 students a question about the case.
	Tutor experience war story	The tutor tells the students a long story that happened in the past during a clinical episode.
	Tutor explanations	The tutor provides a long explanation about a concept.
	Student answers question	Students respond to questions from the tutor.
	Student question to tutor	Students ask questions regarding the case during PPT instruction.
	Tutor as guide on the side	The tutor explains to students that he/she expects students to take command of PPT case discussion.
	Tutor task explanation	The tutor explains the VPS task.
	Tutor role play as patient	The tutor poses as patient during the small group discussion so that students can interview a patient.

Classroom description	Read slides	The student is reading a PPT slide during case instruction.
	Students run PPT	Who controls the mouse during a PowerPoint case led by tutor.
	Transition Time	A section of teacher-student dialog that occurs during a transition between VPS and traditional case instruction.
	Tutor uses white board	The tutor uses the white board to draw diagrams for the benefit of students.
Unforeseen Events	**Code**	**Events that occur during implementation.**
	Internet failure	Internet failure for two minutes.
	Mislabeled video in Arcadia	Researcher was able to retrieve video but it was mislabeled under the wrong small group room code.
	Pass out competency task	A researcher memo about the distribution and collection of the competency task indicates that one tutor distributed it 2 minutes late.
	Recording sound	The recording sound was not perfectly clear for all four cases.

Table R2

Codes for Photographic Data

Table R2 provides the codes used to analyze photographic data using the open coding process described in Chapter 4.

Engagement Level	Category	Code	Description
High Engagement	Very highly engaged	Rapt concentration	All students exhibit very deep cognitive engagement by leaning very close to the laptop.
	Very highly engaged	Pleased expression	At least on student exhibits a pleased or interested expression.
	Highly engaged	Leaning in	Leaning in toward the activity. Body posture seems “Collaborative”
	Highly engaged	Focused on Task	All students are “hard at work” and very much “on task”.
	Interactive	Point	Students point to something on laptop screen, or somewhere in the classroom.
	Interactive	Gesture	Students make a gesture or stretch a limb to illustrate a medical joint issue.
	Interactive	Discuss with professor	Students discuss with the tutor.

	Interactive	Take notes	Students take notes.
	Interactive	Discuss with Peers	Students turn their heads to look at peers, as if discussing
Medium Engagement	Medium level engagement	Passive Pose	All are paying attention, serious expression to the tutor's presentation, passive slightly low energy pose.
	Medium level engagement	Transition time	Some students are finished with the simulation and others are not. Some are working on their own computer, or looking away. Others are chatting with others. Those involved in the simulation are still focused. Some students are filling out competency tasks.
Low Engagement	Low Enthusiasm	Focused, Low energy	At least one student is leaning head on hands, or desk, looking serious or tired. The expression on the student faces gives the scene low energy. -Students are looking down, or looking at their own laptops but not all are paying attention to the PPT or instructor. They do not appear to be very interested. -One student may be reclining or leaning away (bored, tired, stretching, finished). -One of the three students in a peer team may be sitting at an angle making it difficult to see the laptop screen.
	Low Enthusiasm	Less focused	-Students are doing a variety of things: looking down or looking at their laptops. -Leans away: At least one is not paying attention to the lesson, and they don't seem very interested, or they seem 'finished' with the activity.
	Reserved	Closed	At least one student is sitting with arms crossed.*

APPENDIX S

IMAGES PERMISSIONS

IMAGES PERMISSIONS: TEAL-MED/ SOMA

Figure List, Page 1 of 3

Figure 3: The Regional Back Pain Scheme—As Depicted in a VPS

Figure 11: Game Platforms Implemented by the TEAL Team

Figure 12: A Sample VPS Case, with Cost, Score, and Step Meters

Figure 13: Partial Case Map, Branching Design

Figure 14: VPS Competency Areas Aligned to National Standards

Figure 15: A Patient Health Record within a Virtual Patient Case

Figure 16: VPS Written Feedback

Figure 21: Sample Diagnostic Competency Task

Figure 22: A Sample Pre- and Post-test Item

Figure 28: A Control Room Classroom Observation Station.

Figure 50: VPS Mechanisms That Scaffold Students toward Clinical Decisions

Figure 51: Student Discussions about Lab Imaging and Anatomy

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TEAL-MED Team Member /VPS Case Author: Thomas Bennett, DO

Signature: [signature] Date: 2/25/14

TEAL-MED Team Member /VPS Case Author: Noel Carrasco, MD

Signature: Noel M Carrasco Date: 2/25/14

TEAL-MED Team Chair: Frederic Schwarz, DO, FACOFP

Signature: [signature] Date: 2/21/14

SOMA Dean, A. Kay Kalousek, DO, FACOFP

Signature: [signature] Date: 2/24/14

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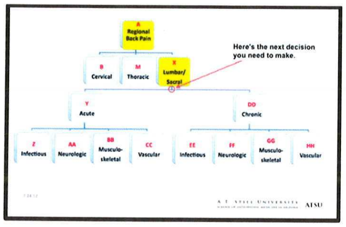

Figure 3

Platform	Use	Duration	Year	Type
Turning Point by Turning Technologies (2010).	Group Practice	5 min.	1-2	**Pause Activities** "Active learning episodes
Quiz Show *Quiz Show, Spin Off and Billionaire* by C-3 Softworks (2010).	Group or Independent Practice	20 min.	1-2	**Case Questions** "Engaging"
Mobile App, Extension Activities *Prognosis ATSU, Prognosis Explain Your Decision, Story Cases* by Medical Joyworks (2010).	Independent Practice	5 min.	3-4	**Linear Case** "Just in time practice"
Virtual Patient Simulations *Decision Simulation* by DecisionSimulation.com (2011).	Group or Independent Practice	25 min.	1-4	**Branching Case** "Training scenarios"

Figure 11

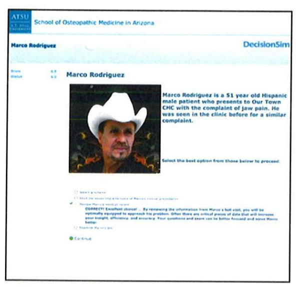

Figure 12

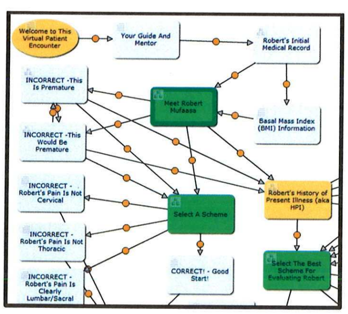

Figure 13

AACOM Competency	The student will be able to..	by…
Patient Care 3.1.j. Perform the patient encounter as appropriate for the situation.	1. Define a clinical presentation.	Choosing an appropriate a scheme
Patient Care 3.1.b Take an accurate history by communicating effectively—verbally and non-verbally—with patients and families in a variety of simulated and/or clinical settings.	2. Gather evidence through a patient history.	Selecting appropriate history investigations.
Patient Care 3.1.d Apply appropriate knowledge to the performance of the physical examination.	3. Use evidence from physical examinations to make clinical decisions.	-Selecting appropriate physical examinations. -Prioritizing PE investigations as either essential vs. non- essential.
Patient Care 3.2.b Generate and test multiple hypotheses during the course of the medical interview and physical examination.	4. Apply pertinent evidence at each decision point in the patient case, by sorting the data through inductive investigation.	Synthesizing evidence to select or prioritize lab and imaging investigations.
Medical Knowledge 2.3.a. Use scientific concepts to evaluate, diagnose, and manage clinical patient presentations and population health.	5. Apply medical knowledge to clinical investigations.	Defining appropriate lab tests/imaging/basic science relevant to the case.
Communication 4.4.a Collaborate with other health care professionals in the care of the patient demonstrating effective personal skills and interpersonal dynamics.	6. Exhibit effective interpersonal dynamics	Working in a student team to make clinical decisions (for team-based simulations).

Figure 14

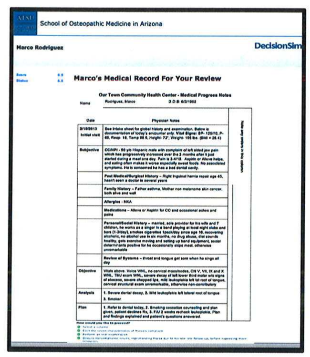

Figure 15

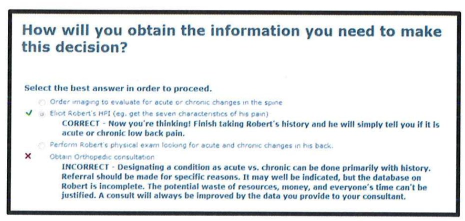

Figure 16

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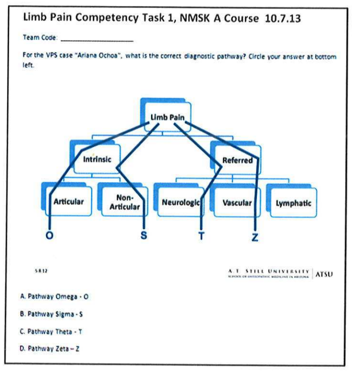


Figure 21

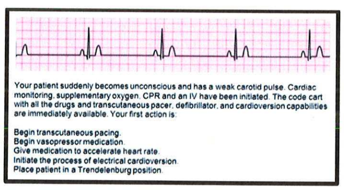


Figure 22

Figure 28

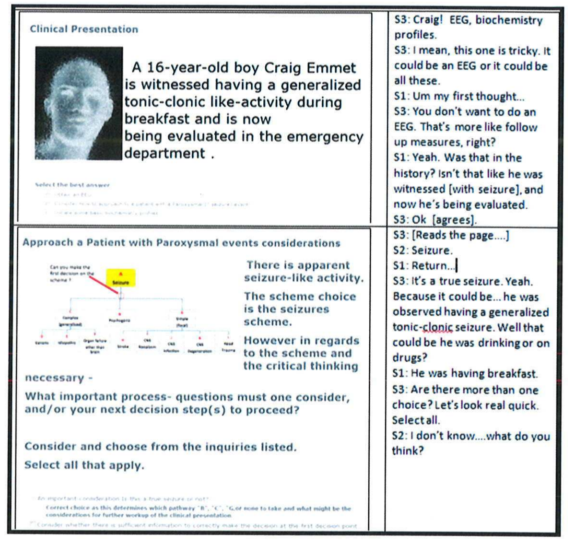


Figure 50

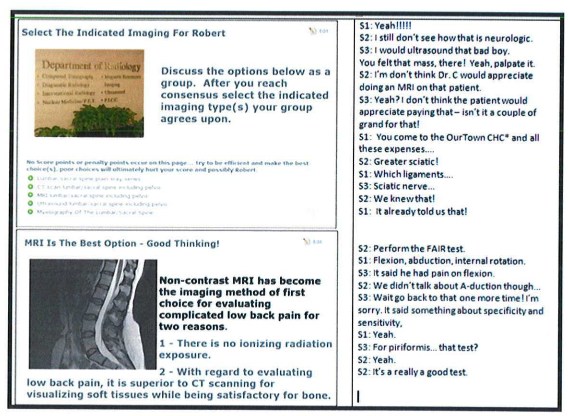
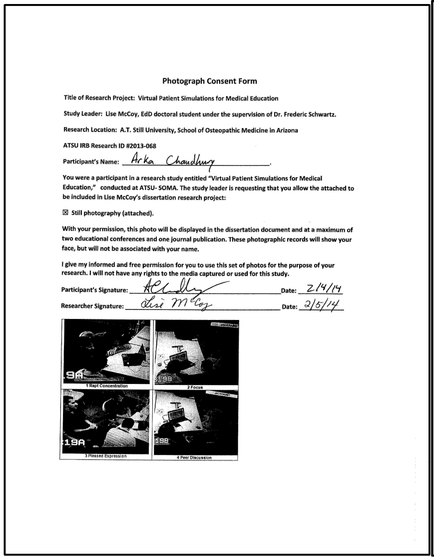


Figure 51

Student Image Permissions



Photograph Consent Form

Title of Research Project: Virtual Patient Simulations for Medical Education

Study Leader: Lise McCoy, EdD doctoral student under the supervision of Dr. Frederic Schwartz.

Research Location: A.T. Still University, School of Osteopathic Medicine in Arizona

ATSU IRB Research ID #2013-068

Participant's Name: Arka Chaudhury.

You were a participant in a research study entitled "Virtual Patient Simulations for Medical Education," conducted at ATSU- SOMA. The study leader is requesting that you allow the attached to be included in Lise McCoy's dissertation research project:

☒ Still photography (attached).

With your permission, this photo will be displayed in the dissertation document and at a maximum of two educational conferences and one journal publication. These photographic records will show your face, but will not be associated with your name.

I give my informed and free permission for you to use this set of photos for the purpose of your research. I will not have any rights to the media captured or used for this study.

Participant's Signature: ______ Date: 2/4/14

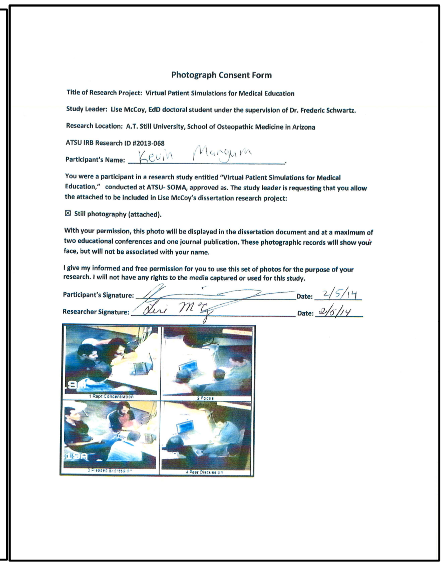
Researcher Signature: Lise McCoy Date: 2/5/14

1 Rapt Concentration

2 Focus

3 Pleased Expression

4 Peer Discussion



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Study Leader: Lise McCoy, EdD doctoral student under the supervision of Dr. Frederic Schwartz.

Research Location: A.T. Still University, School of Osteopathic Medicine in Arizona

ATSU IRB Research ID #2013-068

Participant's Name: Kevin Mangum.

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Participant's Signature: ______ Date: 2/5/14

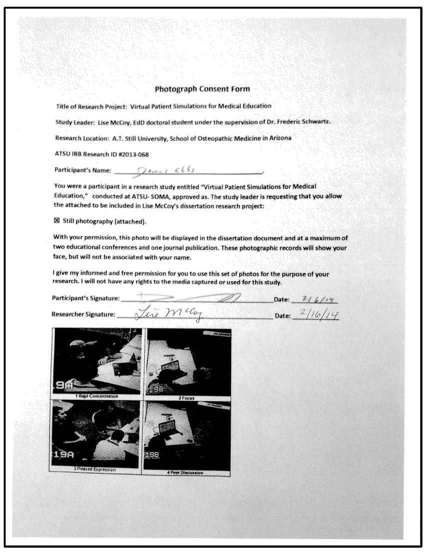
Researcher Signature: Lise McCoy Date: 2/5/14

1 Rapt Concentration

2 Focus

3 Pleased Expression

4 Peer Discussion



Photograph Consent Form

Title of Research Project: Virtual Patient Simulations for Medical Education

Study Leader: Lise McCoy, EdD doctoral student under the supervision of Dr. Frederic Schwartz.

Research Location: A.T. Still University, School of Osteopathic Medicine in Arizona

ATSU IRB Research ID #2013-068

Participant's Name: [illegible].

You were a participant in a research study entitled "Virtual Patient Simulations for Medical Education," conducted at ATSU- SOMA, approved as. The study leader is requesting that you allow the attached to be included in Lise McCoy's dissertation research project:

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Participant's Signature: ______ Date: 2/16/14

Researcher Signature: Lise McCoy Date: 2/16/14

1 Rapt Concentration

2 Focus

3 Pleased Expression

4 Peer Discussion

Image Permission Form

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Research Location: A.T. Still University, School of Osteopathic Medicine in Arizona

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With your permission, this image will be displayed in the dissertation document and at a maximum of two educational conferences and one journal publication.

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Dana Ferrari ______________________ **Date:** 02/03/2014

Researcher Signature: ______________________ **Date:** 2·16·14

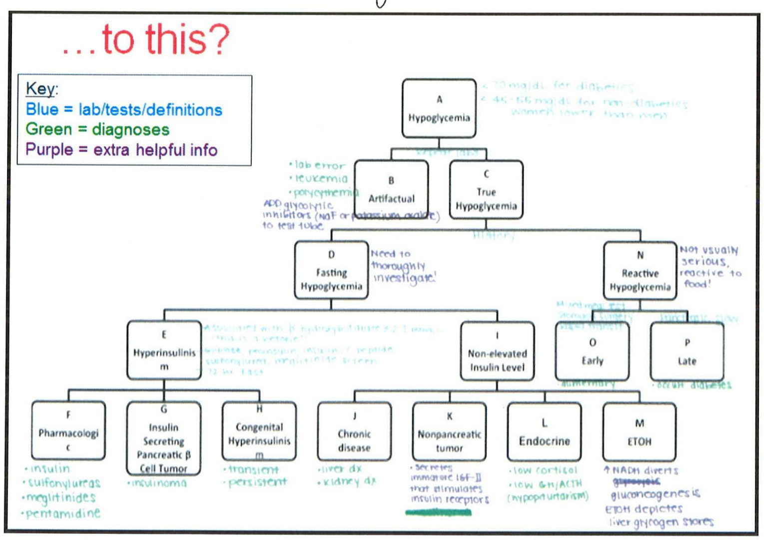

Figure 7. A student's annotation of a clinical presentation scheme.

Note: A first year medical student shows her work, constructing a mental map by adding in the evidence required to make decisions at each node in the scheme. Permission granted for reprinting (Ferrari, 2012).