ABSTRACT

SMITH, NANCY ANN. Facilitation of Physical Therapist Student Hypothetical Deductive Clinical Reasoning Using a Scaffolded Mobile Application. (Under the direction of Dr. Kevin Oliver).

Within the professions of education and medical education, research has demonstrated that computer-based instructional scaffolding can assist learners in developing the practices of scientific reasoning or clinical reasoning, emphasizing either a narrative or scientific reasoning approach. However, there is a paucity of research in the profession of physical therapist (PT) education on using computer-based instructional scaffolding principles to facilitate scientific clinical reasoning. Further, research on the use of mobile technology (MT) to facilitate scientific reasoning is scant in the profession of education, and research is non-existent within PT education on the use of MT to facilitate scientific clinical reasoning. **Methods:** Therefore, this dissertation describes the development, implementation, and evaluation of a mobile application to determine what impact it had on first-year PT student scientific clinical reasoning and what soft scaffolds were most relied upon for facilitating the scientific clinical reasoning process. In developing the mobile application, the researcher utilized the ADDIE instructional design model and utilized principles from the scientific reasoning framework scaffolding model and the Hypothesis Oriented Algorithm for Clinicians II (Part 1) to scaffold PT students' sequence and strategies of scientific clinical reasoning. Three different domains of scaffolding using both hard and soft scaffolds were included in the application: sense making, process management, and reflection and articulation. The mobile application was evaluated by using several data sources. First, the researcher conducted *pre-task-based interviews* to detect the initial reasoning process used by the student-participants that were audio recorded. Second, the student-participants had four sessions with the mobile application. During these sessions with the mobile application *video data* were collected to detect actions taken by student-participants during application use, and *backend data* were collected via application databasing to record the steps taken with and data entered into the mobile application. Finally, following application use, a second *post task-based interview* was conducted to detect possible changes in the reasoning process. During all phases of the study, *researcher field notes* were taken. All data that were collected were evaluated using inductive and deductive qualitative narrative analysis methodology. **Results:** The mobile application had four main effects upon scientific clinical reasoning, namely: improving the sequence and correctness of diagnostic reasoning used by all student-participants, increasing the use of higher-order, more sophisticated reasoning strategies, and changing perceptions of needed supports for clinical reasoning. Needed clinical reasoning supports perceived by student participants as important were: knowledge, past experience, collecting appropriate data, sense making, process management, confidence, and articulation and reflection. Effects of the mobile application identified by student-participants were: allowing for knowledge support, supporting sense-making, articulation and reflection, and process management; allowing repeated practice, and increasing their ability to identify and focus upon the problem. The use of soft scaffolding was supportive for scientific clinical reasoning, soft scaffolds were most needed for knowledge support, and the use of the scaffolds generally decreased over sessions with the mobile application. Suggestions were made by student-participants for improving the mobile application that included increasing the number of cases in the application for more practice opportunities, to correct errors in the debriefing screen (did not always function properly), and to improve support for prescribing treatment. **Discussion and Conclusion:** This dissertation provides the first evidence in PT education that a mobile application using a case-based approach and instructional scaffolding can improve and is perceived to improve PT scientific clinical

reasoning, that soft scaffolds are necessary and supportive for facilitating scientific clinical reasoning, and provides evidence related to student perceptions of needed supports for scientific clinical reasoning. Implications are presented for future research for practice and for application design to facilitate PT student scientific clinical reasoning.

Facilitation of Physical Therapist Student Hypothetical Deductive Clinical Reasoning Using a Scaffolded Mobile Application

by
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DEDICATION

This dissertation is dedicated to my husband, Kevin, my daughter, Ella, and my mom, Linda; and dad, Bill. Thank you for your support and allowing me to complete this work. I would not have been able to complete it without you. To Ella, take advice from Ella Fitzgerald, who said, “Just don't give up trying to do what you really want to do. Where there is love and inspiration, I don't think you can go wrong.”

BIOGRAPHY

Nancy Ann Smith is a physical therapist, a second career teacher, wife, mother, daughter, and a perpetual learner. She grew up in Missouri, Louisiana, and, finally, North Carolina, where she graduated from Southwest Guilford High School in High Point.

After high school, Nancy attended Saint Louis University, Saint Louis, MO, where she earned her B.A. in Psychology, B.S. in Exercise Science, and Master in Physical Therapy degrees, finishing in the year 2000. Following her matriculation, she moved to New Jersey to practice physical therapy. Deciding that she had experienced enough traffic to last her a lifetime, she moved back to Greensboro, NC in 2001, where she practiced physical therapy in the geriatric setting, and married her husband Kevin in 2002. In 2003, she decided to continue her quest for life-long learning by pursuing a Doctorate in Physical Therapy from Saint Louis University, which she earned in 2005. After receiving her Doctor of Physical Therapy degree, she served as a clinical instructor for physical therapy students, and was blessed with her daughter, Ella in 2006.

In 2007, her mentors, Teresa Conner Kerr and Sharon Prybylo, introduced her to teaching with high fidelity human simulators. This introduction led to multiple questions about the effectiveness of teaching with new technologies in the physical therapy classroom, which she explored first during her tenure at Winston Salem State University in 2008 as an adjunct professor, and subsequently as a full-time professor in 2010. Deciding that she needed to continue to learn about the process of educational research in order to answer her questions about the effectiveness of teaching with technology, she pursued and was admitted to the Digital Learning & Teaching Program at North Carolina State University. In 2011, she began her PhD studies at North Carolina State University.

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The premise that we achieve and learn alone is a fallacy. We must depend on the support and encouragement of others in order to be our best selves. To that end, it is important for me to acknowledge those that have helped me along my path in this PhD and dissertation process.

First, I would like to acknowledge the people who inspired me to pursue a PhD in the first place. Teresa Conner-Kerr and Sharon Prybylo, you helped me to initiate this process and have given me thoughtful advice, even when I didn't want it, but needed it. Next, I would like to acknowledge those people who have taught me so much about education and educational research during the coursework stage of the PhD, including my professors and fellow students at North Carolina State University and my colleagues at Wake Forest University, Dan Johnson and Sabrina Sotero. Thank you for giving me thoughtful advice and words of encouragement that have been instrumental in shaping my thought processes and ideas about this dissertation and the mobile application that was developed. Lastly, I would also like to acknowledge the efforts of my committee members who have challenged me to think outside of my physical therapy box, and to situate my ideas in the realm of education. First, thanks go to Kevin Oliver, my committee chair, who patiently listened to my thoughts and ideas, and often gave suggestions to help me narrow my focus. I would also like to thank Andrew Bartlett, who kept encouraging me through the process, always listened to my ideas, and who kept reminding me that the best dissertation is one that is finished. Hiller Spires, you have challenged me first to write my thoughts down and to be open to changing them as I consider new constructs within education that may influence my work. Thank you for your wealth of knowledge and experience. Meghan Manfra, thank you for making me think about the processes and curricular theories of education and how they interact with my first learned profession of physical therapy. Finally, thank you Hollylynne Lee for your thoughtful ideas on how I could best demonstrate how students are learning through qualitative methods and for challenging me to utilize those ideas to produce the best findings.

In considering those who have felt the most effects of this dissertation process, I would like to acknowledge my family, students, and colleagues. First, special thanks go out to my family, including my Mom, Dad, husband, and daughter who often waited for me to get off the computer to go places, cooked dinner, did laundry, cleaned the house, and listened to my ramblings about school and work. Secondly, I acknowledge my students and student-participants who inspired me to keep going even when the thought of a dissertation process seemed daunting, and who persevered in the classroom even when their professor was tired. Finally, I would like to thank my colleagues, who covered for me in clinic, covered classroom time, and kept encouraging me to finish this journey. Without the support of all of you, I could not have completed this study.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

Background and Statement of the Problem

Physical therapist (PT) practice requires practitioners to act autonomously and to make effective decisions that are in the best interest of their patients, all within an ever-changing, complex healthcare environment. Therefore, PT students and practitioners must develop the capability to exercise clinical reasoning, a broad construct that encompasses multiple dimensions and has multiple definitional constructs. Within the physical therapy literature, clinical reasoning has been defined as the cognitive processes and knowledge used to formulate clinical decisions. Other definitions of the clinical reasoning construct may also encompass the process of reaching clinical decisions based upon collected data, the cognitive process of deliberation about an appropriate course of action within a specified clinical context, the process of reflecting on action and in action during the diagnostic process, and the strategies utilized with conditional or narrative reasoning that encompass management of patient care based upon the physical therapist's knowledge, patient goals, patient belief systems, and professional judgment (Edwards, Jones, Carr, Braunack-Mayer, & Jensen, 2004; Smith, Higgs, & Ellis, 2008; Terry & Higgs, 1993; Wainwright, Shepard, Harman, & Stephens, 2010).

In efforts to foster student competence in clinical reasoning domains and processes related to establishing a diagnosis and plan of care, one curricular issue that needs to be addressed by PT educators is a developmental andragogy to facilitate scientific clinical reasoning. This study addresses the need for such an andragogy by examining how a researcher-generated mobile application that applies decisional scaffolds fosters the development of PT students' scientific (hypothetical deductive) clinical reasoning capabilities using a qualitative, sequential, intervention-based approach (Creswell & Clark, 2010; Creswell, 2015). For the purposes of this study, the researcher-generated, case-based mobile application provided decisional scaffolds based on two conceptual frameworks: the scientific reasoning framework scaffolding model (Quintana et al., 2004) and the Hypothesis Oriented Algorithmic Framework for (PT) Clinicians II, Part 1 (HOAC II-1) (Rothstein, Echternach, & Riddle, 2003).

Within PT education, multiple methods have been suggested for developing effective scientific (hypothetical deductive) clinical reasoning skills in PT students. Prominent methods include the use of algorithmic frameworks in classroom-based settings and the use of case-based learning in classroom instructional settings or via computer-aided learning (CAL) modules. Each of these methods has shown some degree of success. In the classroom, case-based andragogical methods have been shown to be successful at increasing PT students' scientific clinical reasoning abilities (Nelson, 2010). Also, in the classroom, algorithmic frameworks have successfully assisted in sequencing and refining PT students' and practitioners' scientific clinical reasoning processes (Jones, 1992; Kenyon, 2013; Rothstein et al., 2003). These algorithmic frameworks, such as the HOAC II-1, employ hypothetical deductive clinical reasoning strategies that expert practitioners utilize when reasoning with challenging or unfamiliar cases, and can provide a methodology that can structure and assist in the development of a novice's clinical reasoning strategy and sequence for use during clinical decision making.

Although a few researchers within PT practice have explored the use of algorithmic frameworks in the classroom or clinical environment to support the development of scientific clinical reasoning (Jones, 1992; Kenyon, 2013), the use of CAL to facilitate scientific clinical reasoning using either case-based approaches, or scaffolding built from an algorithmic reasoning framework has been limited. Currently, only three studies exist within the PT literature that support the use of CAL to facilitate scientific clinical reasoning using a case-based approach, and no study has examined the use of CAL in combination with an algorithmic framework, such as the HOAC II-1, to provide a scaffolded, algorithmic, reasoning-framework-based approach to scientific clinical reasoning (Bayliss & Warden, 2011; Huhn & Deutsch, 2011; Huhn, McGinnis, & Deutsch, 2013; Seif & Debora Brown, 2013). Further, no studies exist within PT on the use of mobile technology (MT) to scaffold the sequence or process of scientific clinical reasoning, either by using case-based methods or case-based methods in combination with an algorithmic framework.

In contrast to PT, the profession of education provides rich body of research on the effectiveness of CAL to scaffold the scientific (hypothetical deductive) reasoning process, assist learners in solving ill-defined scientific problems, and present learners with case-based pedagogy (Demetriadis, Papadopoulos, Stamelos, & Fischer, 2008; Thistlethwaite et al., 2012). These studies have demonstrated the positive effects of structuring (scaffolding) the process of learning scientific (hypothetical deductive) reasoning, mostly in primary and secondary education, which can enable the learner to engage in more efficient and effective discipline-related decision-making (Quintana et al., 2004). However, these studies do not use MT, instead relying on CAL delivered methods. Yet, the use of MT may be helpful for facilitating pedagogy or andragogy for improving scientific clinical reasoning, in two ways: first, by providing just-in-time support for knowledge acquisition, educating users at the moment and place where they need it most; and second, by facilitating the sequence of scientific clinical reasoning by scaffolding its process in classroom or clinical settings (Ally, 2010). Given the educational potential of mobile applications using MT, it is reasonable to explore whether or not MT based application that scaffolds a scientific clinical reasoning process as PT student-participants evaluate cases will provide those student-participants with the ability to acquire skills in the sequence and scope of scientific clinical reasoning.

Purpose of the Study

Previous researchers have not explored the applicability of mobile-based technology applications that use an algorithmic framework, the HOAC II, to scaffold PT students' scientific clinical reasoning processes as clinical cases are evaluated. Further, the use of scaffolding for scientific clinical reasoning processes, while prevalent in educational research using CAL, has not been applied to mobile devices within PT education. To address these gaps in the literature, this study explored how PT student-participants' scientific clinical reasoning sequences and clinical reasoning strategies are influenced by a researcher-developed mobile-based application that employed scaffolds to the HOAC II-1 clinical reasoning algorithm as students performed evaluation of cases. A further point of study was to address the gap in the PT literature related to the scaffolds needed to support student-participants' scientific clinical reasoning when MT is utilized with a patient case. The following research hypotheses and questions were addressed.

Research Questions

Overarching Research Question

The overarching question was as follows: How are PT student-participants' scientific clinical reasoning —specifically their evaluation and examination processes (related to hypothesis generation), their clinical decision-making (regarding treatment appropriateness), their use of clinical reasoning strategies, and their sequencing of scientific clinical reasoning — influenced by a mobile application that provides scaffolds to the HOAC II-1 clinical reasoning process?

Sub-questions Related to the Problem

Two sub-questions were explored in order to elucidate facets of the overarching research question.

Research question 1. How are PT student-participants' clinical reasoning strategies and sequence of scientific clinical reasoning and hypothesis generation influenced by a mobile application's scaffolding of the HOAC II-1 framework?

Research Question 2. What soft scaffolds within the mobile application do PT student-participants rely upon most often to inform their scientific clinical reasoning process, and how does that reliance change over three different practice sessions?

Research Approach

This study utilized an intervention-based, sequential, qualitative design (QUAL→ QUAL → QUAL) (Creswell, 2010; Creswell, 2015). Data were collected prior to, during, and following the intervention, which consisted of a *pre-test qualitative task-based interview*, *qualitative user inputs into the mobile application* and *video-based data* obtained during four different scheduled practice opportunities. At the first practice opportunity, PT student-participants were instructed in application use. In the three subsequent practice sessions, PT student-participants worked through three different patient cases (one per session), which were selected by participants after reading an introductory textual description of cases present in the mobile application. Following all of the practice sessions, PT student-participants engaged in a *post-test qualitative task-based interview*. Data were analyzed using a qualitative deductive *a priori* narrative analysis approach and inductive analysis approach. Following analysis, findings were described using a collective case-based approach (that presented across case themes and highlighted individual differences, in order to depict changes that occurred post intervention related to student-participant's scientific clinical reasoning sequence or strategies, perceptions about clinical reasoning, and perceptions about the impact of the mobile application. Further qualitative analysis of video-based data using a within and across case approach (collected while the application was in use) was performed to analyze which soft scaffolds were most relied upon to support the clinical reasoning process by the PT student-participants and to determine how the mobile application affected the reasoning process. A further analysis based upon video data collected during application use and user comments was conducted to provide implication for future application design/re-design.

Conceptual Framework

A conceptual framework for this study is synthesized from three different theoretical constructs: (a) an algorithmic model provided by the Hypothesis-Oriented Algorithmic Framework for Clinicians II, part 1 (HOAC II-1); (b) Quintana et al.'s (2004) model of how technology scaffolds hypothesis-driven (scientific) inquiry; and (c) Gilliland's (2014) work on student clinical reasoning strategies. Together, these three components make possible to investigate and create an understanding of how: clinical reasoning strategies evolve with teaching methods, scaffolding supports the development of learning and scientific reasoning in technology-rich environments, and the HOAC II-1 algorithmic sequential framework supports scientific clinical reasoning within PT students.

HOAC-II

First, the conceptual framework is informed by the algorithmic model provided by the HOAC II-1 (Figure 1.1, below, from (Rothstein et al., 2003, p. 459-460), Oxford University Press, used with permission)

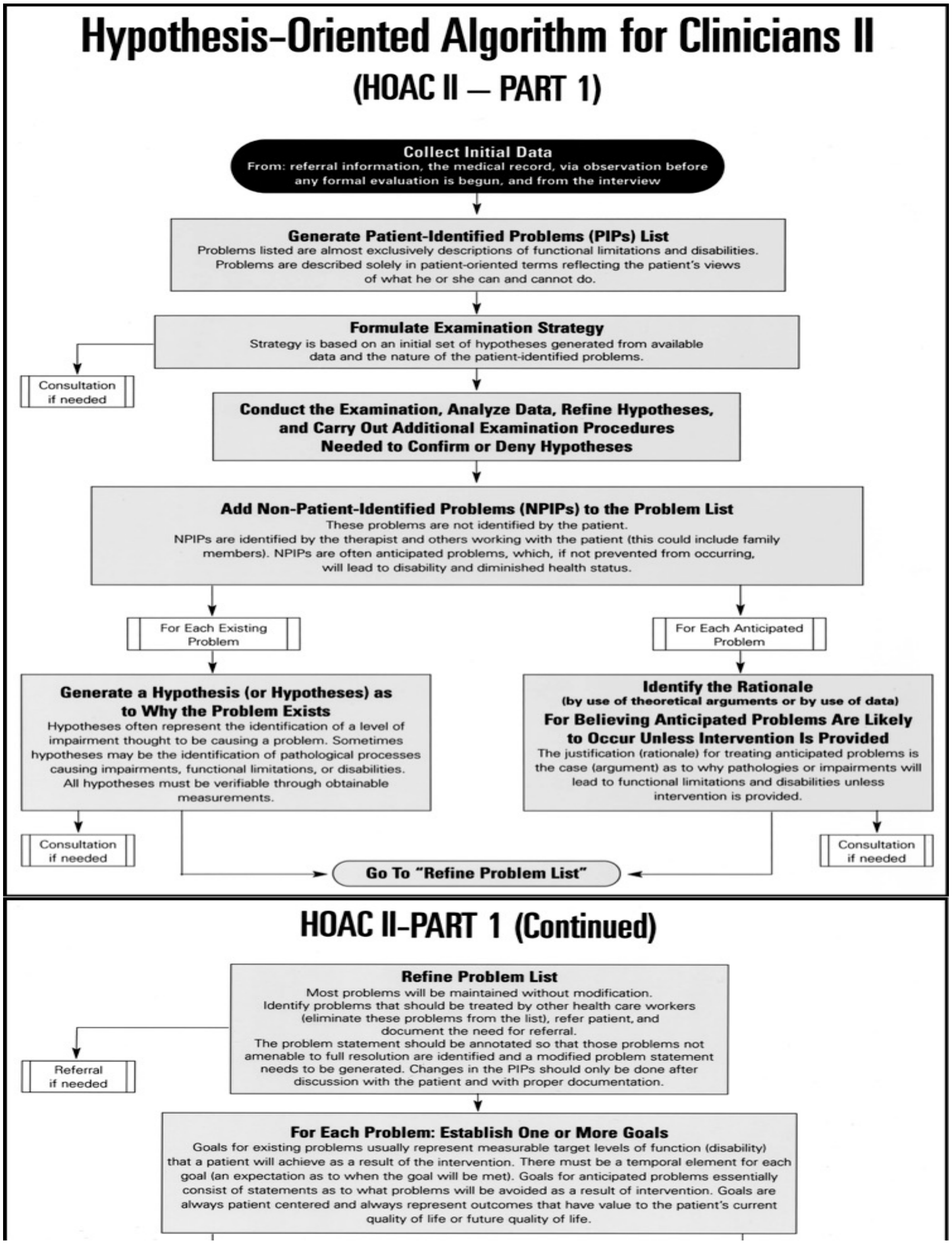


Figure 1.1. The Hypothesis Oriented Algorithmic Framework II-1 (Oxford University Press, used with permission).

The HOAC-II is an algorithmic framework that has been suggested as a methodology to improve scientific clinical reasoning in physical therapy (Jones, 1992; Kenyon, 2013). Within this conceptual framework, the HOAC II-1 was utilized to provide a structure and sequence to PT student-participants' clinical reasoning process as they worked through a complex case while using the mobile application. A further use of this theoretical construct was to act as an *a priori* mechanism for analyzing the sequence of the reasoning process utilized by PT student-participants during the *pre- and post-test interviews* and while the mobile application was in use.

The HOAC II-1 was initially developed to facilitate better scientific clinical reasoning in clinicians, by emphasizing the use of data in formulating hypothesis-driven or pattern recognition strategies, which are commonly used by both entry-level and expert practitioners. Another goal of the HOAC-II-1 was to assist in improving the diagnostic process and decreasing errors (Rothstein et al., 2003). One consideration when using this algorithm is to establish whether its use leads to more accurate decision-making or a more refined and sequential form of scientific clinical reasoning in PT students and practitioners. Research has shown that, in practitioners, the HOAC II framework can facilitate and improve reasoning in pediatric and manual therapy (Kenyon, Lisa, 2013; Jones, Mark A, 1992, respectively). Further, studies with students have found that the use of external frameworks, such as the HOAC II, that emphasize hypothetical deductive reasoning, can provide scaffolding that allows the development of more sophisticated clinical reasoning strategies (Gilliland, 2014).

To aid practitioners in applying this algorithm, Rothstein, Echternach, and Riddle (2003) provided definitions for the terms in this model, relayed in the sequential order in which they are utilized, as shown in Table 1.1, below.

Table 1.1. Framework Definitions Used in this Study (Rothstein, et al., 2003).	
Step in the Framework	Definition
Collect Initial Data	Collecting information using questioning/interviewing including: the patient history, patient expectations, and patient's observations about their condition. May include reviewing the medical record/case history.
Generate Patient-Identified Problems List	Recording a patient report of the problems that describe reasons for coming to physical therapy, listing patient-identified limitations, listing functional impairments, and patient concerns about future limitations.
Formulate Examination Strategy	Determining the need for further information based upon initial data collection and patient-identified problems. The PT identifies what initial hypotheses exist and what tests are needed to confirm or deny these hypotheses. The PT provides a rationale for generated hypotheses.
Consultation if Needed	The PT seeks outside assistance or support from other practitioners. The PT seeks outside assistance or support from other practitioners prior to conducting any form of objective examination of the patient.
Conduct the Examination, Analyze Data, Refine Hypotheses, and Carry out Additional Examination Procedures	The PT employs evidence-based research, tests and measures, and data that are concisely organized to confirm or deny initial hypotheses. Data is gathered data from tests in organized format. A rationale is formulated for refuting/accepting hypothesis. The physical therapist notes when additional procedures i.e.: medical tests are needed.
Add Non-Patient-Identified Problems to the Problem List	The PT documents: existing problems that the patient did not identify, problems that need to be addressed to prevent further disability, and examination findings that are significant to the problem identified.
Generate a Hypothesis as to Why the Problem Exists	The PT provides a rationale for the final diagnostic hypotheses generated. The final physical therapy diagnostic hypothesis is identified for patient-identified problems and non-patient-identified problems. These hypotheses are phrased in pathologies, functional limitations, disabilities, and impairments, and provide a reason for intervention.
Identify the Rationale by arguments or data for Believing Anticipated Problems are Likely to Occur Unless Intervention is Provided	The PT provides a justification for the hypothesis generated and presents arguments based upon data gathered during examination. The therapist provides justification for treating patient-identified and non-patient-identified problems.

Table 1.1. (continued).

Refine Problem List	The PT refines the problem list to only include problems that the physical therapist is able to treat. The therapist gives justification for treating the patient.
For Each Problem Establish One or More Goals	The PT establishes target levels of function that the patient should achieve through intervention.
Referral if Needed (at any point in the process)	The PT refers to other providers if the problem is outside of the physical therapist's scope of practice. The PT provides justification of the need for referral. This referral can occur at any step in the decisional process but is most likely to occur as different types of data are collected and analyzed, or at the conclusion of the data collection process.

Scaffolding Design Framework for Scientific Inquiry

The second element of this study's conceptual framework is the scaffolding design framework for scientific inquiry, a model posited by Quintana et al. (2004) that was first used to explain the role of technology in scaffolding hypothesis-driven (scientific) inquiry. The components of this model are shown in Table 1.2, below, which demonstrates the scientific inquiry component supported, the definition of that component, and the possible strategies utilized for scaffolding.

Table 1.2. The Scaffolding Design Framework for Scientific Inquiry, Adapted from Quintana, et al. (2004).

Scientific Inquiry Component Framework Term	Definition	Strategies Used for Scaffolding and Definitions

Table 1.2. (continued).

Sense Making	Refers to how individuals proceed through the process of scientific inquiry— "generating hypotheses, designing comparisons, collecting observations, analyzing data, and constructing interpretations" (p. 344). Involves looking for patterns in the data, identifying data that is relevant, and drawing inferences.	Guideline 1: "Use representations and language that bridge learners' understanding" (p. 347). This guideline focuses on strategies to help individuals build knowledge, including incorporation of knowledge support to build scientific practices, structuring the tool using a framework, or using concept diagrams to allow learners to see the process. Guideline 2: "Organize tools and artifacts around the semantics of the discipline" (p. 351). This entails the use of technology to help learners to think about the steps they need to take in their work through the structure of the software by providing relevant data choices or by asking students to record their analyses. Guideline 3: "Use representations that learners can inspect in different ways to reveal important properties of underlying data" (p. 353). This guideline involves creating ways of representing data in patterns, enabling learners to manipulate different parts of the data and see the results; it also involves allowing learners to see the relationship between figural representations and the data.
Articulation and Reflection	Learners construct and articulate an argument, requiring learners to review, reflect upon, and evaluate results. Learners also have to create explanations for their thoughts, monitor their thought processes, and decide where their thinking processes are strong, and where they need to be strengthened.	Guideline 7: "Facilitate ongoing articulation and reflection during the investigation" (p. 370). This deals with having learners perform tasks to monitor how the task is progressing, document results, and reflect upon actions taken during and after the scientific reasoning process.

Table 1.2. (continued).

Process Management	Assisting learners in making decisions about the steps they need to take when undertaking scientific reasoning.	Guideline 4: "Provide structure for complex tasks and functionality" (p. 359). This guideline deals with helping learners by limiting the scope of activities into stepwise processes, limiting the amount of data presented, helping learners visualize the process of reasoning, decomposing a task into smaller steps, presenting organizational strategies within the application, or providing constraints to the information presented. Guideline 5: "Embed expert guidance about scientific practices" (p. 363). This entails helping learners understand how experts go about reasoning, providing information related to expert practices, or providing hints or prompts to guide the investigation. The strategy involved here is related to telling the learner what strategies are most important to pursue from an expert perspective. Guideline 6: "Automatically handle nonsalient, routine tasks" (p. 366). The software performs routine tasks such as summarizing data, drawing diagrams, databasing and returning information, organizing data into meaningful units through data logging, and organizing the navigational tools in a consistent manner.

In addition to explaining the role of technology for providing scaffolding for learning, a second reason for utilizing this model within the study was to inform the design of scaffolding supports within the mobile application. By using this model, the design of the mobile application was structured to provide supports for the three different domains (sense making, process management, articulation and reflection) (Quintana, 2004) of scientific, hypothetical deductive clinical reasoning, a type of reasoning for which learners typically need support. A final reason for using this model within this study was to provide a theoretical lens to analyze what types of soft scaffolds were accessed by students as they were undertaking the reasoning process while the mobile application was in use and for analyzing what scaffolds were needed to support reasoning during the *pre-* and *post- task-based interview*.

Clinical Reasoning Strategies

Finally, this study's conceptual framework is informed by work on clinical reasoning strategies that was conducted by Gilliland (2014) in order to understand how students, develop clinical reasoning as they progress towards becoming PT practitioners. Building on earlier work on clinical reasoning differences in novice and expert PT practitioners, Gilliland (2014) defined the types of clinical reasoning approaches that students often undertake when reasoning through a clinically based case. These strategies, ordered in the sequence in which they tend to be acquired in PT students, from the level of trial and error to the highest order, pattern recognition, are shown in Table 1.3, below. The clinical reasoning strategy, reasoning about pain, outlined within the table below, is used similarly by novice practitioners and experts, and therefore is generally regarded by Gilliland (2014) to be non-hierarchical and contiguous with the other clinical reasoning strategies.

Table 1.3. Clinical Reasoning Strategies, Adapted from Gilliland (2014).

Conceptual Framework Term	Definition
Clinical reasoning Strategy: Trial and Error	No initial plan for reasoning or hypothesis generation; reasoning appears randomly generated; no clear movement from one structure to another
Clinical reasoning Strategy: Following Diagnostic Protocols	Trying to recall information from class; using evaluation forms from class

Table 1.3. (continued).

Clinical reasoning Strategy: Rule-in, Rule-out	Beginning with one or more hypothesis, reasoning about that hypothesis, and moving on to another hypothesis
Clinical reasoning Strategy: Hypothetical-Deductive	Generating hypotheses and using an organized plan of testing to rule out or rule in. Demonstrates ability to shift hypotheses when faced with contradictory information.
Clinical reasoning Strategy: Pattern Recognition	Making a primary hypothesis to describe the patient condition from prior experience, or from a matching patient description from previously encountered patient case. Using examination to confirm a hypothesis and explaining data findings in light of diagnosis.
Clinical reasoning Strategy: Reasoning about Pain	Using the pain description and aggravating/relieving factors to guide reasoning. Considering chronicity, severity, and irritability. Contiguous with other strategies and utilized equally by novice and expert practitioners.

The clinical reasoning strategies emphasized in this conceptual framework may be used by PT students as they collect patient data (perform the examination) or form diagnostic hypotheses (generate an evaluation). These strategies are not accounted for in the HOAC II-1 framework, as students do not typically utilize only hypothetical deductive reasoning when they are first beginning to reason clinically. Rather, novice practitioners and physical therapy students have been noted to employ multiple methods of clinical reasoning during the examination process. These strategies include trial and error, following diagnostic protocols, hypothetical deductive reasoning (more advanced student), pattern recognition (more advanced student), and reasoning about pain (both novices and experts) (Gilliland, 2014). Just as more experienced PT practitioners advance in their clinical reasoning as expertise is developed, so too, students develop clinical reasoning along a continuum (as noted in Table 1.3 above) (Gilliland, 2014).

As clinical reasoning is developing, additional issues are found as clinical decisions are being made by both novice PT practitioners and PT students. These issues include collecting too much data, utilizing faulty reasoning strategies, or making more errors due to biased thinking

(Doody & McAteer, 2002; Gilliland, 2014; Rothstein et al., 2003). However, as practitioners and students become more experienced, their hypothesis generation becomes more refined, they make more precise interventions and assessments, and they consider more factors in their diagnostic and prognostic processes (Gilliland, 2014), thereby reducing diagnostic errors. In this study of PT students, the use of this work on clinical reasoning development in PT students enables us to apply a theoretical lens to analyze which clinical reasoning strategies students use initially, and then subsequently, after working with the mobile application.

Applying the Conceptual Framework

The three components of the conceptual framework—the HOAC II-1, the scientific scaffolding design framework model, and clinical reasoning strategies—are all necessary for framing this study because each one provides a different facet for understanding the questions at the heart of this study: how clinical reasoning strategies used by PT students change with use of the mobile application, how scaffolding supports the development of learning and scientific clinical reasoning in technology-rich mobile environments, and how the HOAC II-1 algorithmic sequential framework supports scientific clinical reasoning. By using these three theoretical constructs, to formulate a conceptual framework, it is possible to discover whether a mobile application that is structured using the HOAC II-1 provides a faciliatory mechanism that allows PT students to use the clinical reasoning strategies that are more often utilized by expert practitioners, and formulate a conceptual model to support clinical reasoning. Moreover, it may also be possible, through further investigation of this application, to determine whether this type of scaffolding provided by the mobile application allows a more sequential procedural schema to be employed, one that better enables diagnosis and treatment of patients through the use of different types of scaffolding and the employment of stepwise algorithm for evaluation and examination, the HOAC II-1.

By using the HOAC II-1, the scaffolding design framework for software to support scientific inquiry (Quintana, et. al., 2004), and the clinical reasoning strategies proposed by Gilliland (2014), an explanatory model is postulated. This model contributes a theoretical and conceptual foundation and an interpretive mechanism for understanding how a researcher-generated mobile application may scaffold and facilitate scientifically based clinical reasoning in PT students.

Inquiry Worldview

This study of whether a mobile application effectively scaffolds and organizes scientific clinical reasoning will employ as its methodological lens a social constructivist orientation. Within social constructivism, “multiple realities are constructed through our lived experiences” (Creswell, 2012). Therefore, reality is co-constructed dialogically between the experiences of the researcher and the subject, resulting in data being derived from each of these individual perspectives (Creswell, 2012). This philosophical framework allows the researcher to explore how tools that use dialogic discourse, like that used in the mobile application, can mediate individual learning. Further fostered by the framework is an understanding of how knowledge, provided at an appropriate time, permits learners to progress from initial, limited engagement in complex modes of problem solving into different modes of thinking that allow more complex problem solving (Mahn, 1999; Verenikina, 2003). By using a social constructivist approach with qualitative data, individual perspectives and learning experiences may be collected and evaluated; in the case of this study, this qualitative analysis may provide substantiation for the effectiveness of a mobile application in improving the types and sequence of clinical reasoning utilized by PT students, and assist the researcher in determining what scaffolds assist learners' development of clinical reasoning.

Rationale and Significance of the Study

When considering the use of various delivery methods or media for content delivery, learning should not differ, as long as the knowledge presented is the same (Clark, 1994). Congruent to this assertion, studies on the use of CAL within PT and medicine have demonstrated that this andragogy can indeed facilitate different facets of clinical reasoning (Cook, Erwin, & Triola, 2010; Veneri, 2011). However, while classroom-based and CAL have been demonstrably effective for scaffolding the processes and domains of clinical reasoning, these methods are not sufficient in themselves. The clinical environment is demanding, and flexibility is required when designing structures to support students' clinical reasoning in ways that best ensure safe patient management. Clinical reasoning and hypothesis generation do not occur exclusively in the classroom, at the centralized charting station, or in the home setting, but instead in the context of a patient encounter or within the laboratory setting. Therefore, for facilitating student learning in the domains of clinical reasoning, the use of mobile technology (MT) has been theorized as being a more effective strategy than using CAL in the classroom due to its portability.

In recent years, researchers within medicine and PT have advocated for the use of MT within the classroom and clinical environment. Justification for this position is found in Kozma (1994), who argued that learning may be enhanced when the media interacts with the environment around it, or it interacts with the cognitive and social processes by which knowledge is constructed (Kozma, 1991, p. 7). Further building on Kozma's (1994) argument, researchers within medicine and PT have explicated the learning-extension features that are unique to mobile devices. First, MT may cause increased interaction with the patient and learning opportunities provided (Mayfield, Ohara, & O'Sullivan, 2013; Premkumar, 2011) due to its portability and accessibility. MT also provides contextual, situated learning, which is constructed by the student in the clinic or laboratory, by providing supports for both “just-in-time” knowledge and scaffolds for the sequence of the student’s diagnostic process (Ally, 2010; Coulby, Hennessey, Davies, & Fuller, 2011; Premkumar, 2011). As the knowledge and supports are situated within the learning environment of the laboratory or clinic, knowledge may be extended, and students’ abilities to reason from their own experience may be increased (Sharples, 2000). MT may also provide flexibility in assessment (Coulby, Hennessey, Davies, & Fuller, 2011), which is “matched to the ability of the learner, offering diagnosis and formative guidance that builds on success”(Sharples, Taylor, & Vavoula, 2005, p. 3). Further, while not extensively studied in medical disciplines, MT may provide a medium from which to facilitate the social and emotional domains of reasoning, due to the pervasiveness of this technology (Premkumar, 2011).

In this study, by utilizing MT, incorporating case-based andragogy, and implementing scaffolding for the scientific reasoning process though use of the HOAC II-1 framework, a novel approach is proposed to extend the advancement of clinical reasoning strategies and assist learners in developing the sequential ordering of the reasoning process. This study is needed due to the paucity of literature on the use of MT to facilitate clinical reasoning in physical therapy education, and due to the lack of research in PT education and the limited literature in education related to the use of scaffolding educational processes for scientific reasoning using mobile devices. Further, since other professions such as science and medicine teach students how to utilize a hypothesis-oriented process, this application, if successful, could be adapted for use in other disciplines to allow students to be better supported in generating hypotheses from collected data, and thus better equipped to make appropriate decisions.

Limitations, Delimitations, and Assumptions on the Part of the Researcher

This research has several limitations. The first limitation relates to the use of MT to facilitate clinical reasoning in PT students. Even if appropriate supports are provided, there is a possibility that individuals may use faulty reasoning sequences or strategies due to their lack of subject-matter experience and knowledge. Further, the fact that individuals may be prompted to make a clinical decision when using the application may lead them to make errors in reasoning in that they might decide to intervene at moments when withholding care would be the more appropriate course of action (commission bias) (Croskerry, 2002).

Further limitations relate to the sample under study. Since the sample is derived from a single institution, which is public and primarily minority-attended, there is a possibility of sampling bias. Students may not be representative of the population of physical therapy students across the country, since most physical therapy students are of majority backgrounds, attend primarily non-minority institutions, and many attend private institutions. Another source of sampling bias may be the stratification procedure that is utilized, since it is not known whether this stratification will produce a representative sample from the population. An additional sample-related limitation arises from the differences in teaching and instructional delivery amongst physical therapy programs, which might limit the application's utility in teaching physical therapy students. In other words, even if the application is effective with the study student-participants, it may not work as well for students at other institutions that do not share similar teaching pedagogies, curricular design, or student characteristics. For these and other reasons, including that the sample size is small, generalizability to other students in other programs may be limited.

The final limitations arise from the use of a think-aloud protocol in the data collection process. When using this technique, it is beneficial to have a trained evaluator to administer it (Krahmer & Ummelen, 2004). In this study, the evaluator administering the protocol has utilized a think-aloud strategy when teaching in the classroom or clinic but is not formally trained in its use. Also, when thinking aloud, the thought process may be slowed or individuals may find it unnatural because it represents a departure from a preferred method of communication (Krahmer & Ummelen, 2004). In addition, the cognitive load provided by the think-aloud method, which requires student-participants to both think and verbalize their thought processes, may be difficult for student-participants to handle (Johnstone, Bottsford-Miller, & Thompson, 2006). For these reasons, the think-aloud process may not give a full picture of the thought processes that are occurring within the subject.

Subjectivity Statement

The researcher conducting this study is an Associate Professor of Physical Therapy and a Board-Certified Clinical Specialist in Geriatrics. This researcher has taught physical therapy courses since 2008 in the primary subject areas of cardiovascular and pulmonary physical therapy and geriatrics. In the classroom, the researcher teaches students conceptual frameworks and strategies to enable them to perform critical reasoning and decision-making to form hypotheses using case-based approaches. As this researcher has gained more experience in the classroom, this researcher has noted that novice physical therapy practitioners and physical therapy students have difficulty assembling data to form hypotheses using a hypothesis-oriented algorithm. More specifically, this researcher finds that PT students tend to be good at collecting data but have difficulty synthesizing data to formulate a patient diagnosis or make a clinical decision toward the appropriate methodology for treatment. Further, students also have difficulty figuring out which data is pertinent to the patient problem, or which data to collect in addition to data already collected in order to become more certain in their diagnostic processes.

Currently, this researcher utilizes technology in the classroom to increase active learning through the use of various media, including human patient simulation, video, and web 2.0 tools. This researcher has created and assisted in the evaluation of a mobile application to help physical therapy students learn assessment skills, discovering that it supported knowledge acquisition, student self-efficacy, and psychomotor skill development (Bartlett & Smith, in review). This researcher believes that technology is a valuable tool for teaching. However, based on a strong desire to create an equity andragogy in this researcher's classroom, this researcher is also concerned with technology's effects on communication, particularly the differential ways that technology is used and experienced by individuals from different socioeconomic and racial backgrounds. Of particular concern is whether and how different groups of students understand material presented via technology.

Assumptions in the Role of the Researcher

Several assumptions have been made in developing this study. The first assumption, based upon previous research, is that different cohorts of PT students differ in their clinical reasoning strategies (Gilliland, 2014). Therefore, the mobile application may be experienced differently by differing cohorts of physical therapy students and may not affect some students as much as others.

A second assumption, also based upon previous studies, is that CAL may be utilized to facilitate clinical decision-making and hypothesis generation in PT students (Bayliss & Warden, 2011; Huhn et al., 2013). More specifically, it is assumed that MT is the most appropriate educational delivery medium for facilitating clinical reasoning, since it can be effective in positioning supports for learning where and when they are needed (Ally, 2009}; in this case, they are situated on-demand to facilitate the growth of clinical reasoning (Premkumar, 2011, citing Barneveld & Shaw, 2006).

Finally, two assumptions are made about the users of this application. First, an assumption is made that students are competent in the use of a mobile device. Unpublished data from a study of physical therapy students conducted by this researcher revealed that all students use a mobile device or smartphone daily or multiple times per day. The second assumption made is that students will understand the conditions presented in the cases, due to their previous work in either undergraduate studies or in the physical therapy program. Further, it is also assumed that if they do not understand the conditions or tests presented, they will utilize the help features located within the application.

Definition of Key Terms

Physical therapy. An allied health profession that focuses on the restoration of movement and function by addressing impairments that occur in neurological, musculoskeletal, integumentary, and cardiovascular systems (American Physical Therapy Association, 1999).

Mobile learning or m-learning. E-learning that takes place utilizing mobile devices such as mobile phones, tablets, and laptop computers. E-learning in this context is the use of synchronous or asynchronous instruction using computer-based media to teach concepts essential to practice (Grant, 2008; Koshmahl, 1994). M-learning differs from e-learning in that it is personal, situated in the learner’s context and location, available everywhere, integrated with daily activities, and portable (Kukulska-Hulme & Traxler, 2005).

Mobile Technology (MT). Devices such as mobile phones, tablets and laptop computers (Grant, 2008; Koshmahl, 1994).

Clinical Reasoning. The cognitive processes and knowledge used to formulate clinical decisions. Other definitions of the clinical reasoning construct may also encompass the process of reaching clinical decisions based upon collected data, the cognitive process of deliberation about an appropriate course of action within a specified clinical context, the process of reflecting on action and in action during the diagnostic process, and the strategies used with conditional or narrative reasoning that encompass management of patient care based upon the physical therapist's knowledge, patient goals, patient belief systems, and professional judgment (Edwards, Jones, Carr, Braunack-Mayer, & Jensen, 2004; Smith, Higgs, & Ellis, 2008; Terry & Higgs, 1993; Wainwright, Shepard, Harman, & Stephens, 2010).

Hypothesis-Oriented Algorithmic Framework for Clinicians II (HOAC-II). An algorithmic framework in PT that provides a scaffolding framework for examination (collection of patient data) and evaluation (formulation of diagnostic hypotheses and plans of care), using a hypothetical deductive (scientific) clinical reasoning strategy (Rothstein, Echternach, & Riddle, 2003).

Hypothetical deductive (or scientific) clinical reasoning. A stepwise process of clinical reasoning which consists of "attending to initial cues or data, forming tentative hypotheses, analyzing patient information, collecting more data, interpreting new data, and re-evaluating hypotheses" (Edwards et al., 2004; Patel, Arocha, & Zhang, 2005; Payton, 1985). This type of reasoning may also include the reflective processes that occur during the diagnostic process and after a diagnosis is made.

Scientific Reasoning. The process of solving ill-defined problems using a hypothetical deductive process that involves consideration of the problem at hand, articulation of ideas or theories as to why the problem exists, generation of theoretical constructs to test related to the problem, obtaining data, and recognizing confirming and disconfirming data, reflecting upon their process of thinking, and, finally, drawing conclusions about causal factors that may relate to the problem at hand (Kuhn, 1993; Zimmerman, 2000).

Scaffolding. Defined as "expert support for a novice's learning" (Sharma & Hannafin, 2007, p. 27), "strategies that enable learners to do things that they cannot do on their own" (Bruning, Schraw, & Ronning, 1999, p. 98).

Organization of the Study

Chapter 1 presented the rationale and significance of the study and outlined the problem and the research question. Chapter 2 reviews relevant literature on four interrelated conceptual strands: (1) the uses of clinical reasoning in physical therapy, the uses of scientific reasoning (via hypothetical deductive strategies) in education, and the ways in which clinical reasoning is progressively developed through experience; (2) the role of scaffolding and algorithmic frameworks in facilitating clinical reasoning; (3) the role of educational methods in facilitating clinical reasoning; and (4) the role of technology-based scaffolds in education in general as well as PT education in particular. Chapter 3 describes the application design and development. Chapter 4 describes the study methodology. Chapter 5 presents the data analysis methods utilized for interview data and the findings related to changes in clinical reasoning, using a collective case approach. Chapter 6 presents the data analysis methods utilized for video and backend application data and the findings related to the need for scaffolding and recommendations for application design using a within and across case approach. Finally, Chapter 7 provides conclusions and recommendations arising from the study.

CHAPTER TWO: LITERATURE REVIEW

This study is underpinned by multiple theoretical constructs derived from the profession of education in general, and particularly from PT education. First, it is supported by understandings of scientific reasoning in education and clinical reasoning in PT. Secondly, it is informed by the use of instructional scaffolding to facilitate the scientific reasoning process with the use of clinical cases, the use of the scaffolding design framework for scientific inquiry, and an established clinical reasoning model, the Hypothesis Oriented Algorithm Framework II (HOAC II-1). Third, this study is informed by understandings of how problem-solving differs between expert and novice practitioners. Finally, the study is influenced by work on the utility of computer-based and mobile-based technologies to scaffold the development of skills necessary for efficient scientific reasoning or scientific clinical reasoning within PT.

This study aimed to determine whether a case-based mobile application that includes prompted scaffolds (based upon the HOAC II Part 1 [HOAC II-1] algorithmic framework), was able to facilitate the process of scientific clinical reasoning and inform clinical decisions. In order to address this aim, the following research question was explored: How are PT student-participants' scientific clinical reasoning—specifically their evaluation and examination processes (related to hypothesis generation), their clinical decision-making (regarding treatment appropriateness), their use of clinical reasoning strategies, and their sequencing of scientific clinical reasoning—influenced by a mobile application that provides scaffolds to the HOAC II-1 clinical reasoning process? The two sub-questions were as follows: (1) How were PT student participants' clinical reasoning strategies and sequence of scientific clinical reasoning and hypothesis generation influenced by a mobile application's scaffolding of the HOAC II-1 framework? (2) What soft scaffolds present in the mobile application did physical therapy student-participants rely upon most often to inform their scientific clinical reasoning process, and how did that reliance change over three different practice sessions?

To contextualize these research questions, this literature review comprehensively reviews literature on several themes: understandings of scientific reasoning using a hypothetical deductive process within education, particularly with respect to scientific clinical reasoning within medicine and physical therapy and their derivations; the HOAC-II-1 scientific clinical reasoning model and its role in facilitating scientific clinical reasoning; and educational methodologies, utilized to facilitate ill-defined problem solving and clinical reasoning within education, medicine, and PT. Included in this discussion is the role of computer-based or mobile-based media in facilitating scientific clinical reasoning or hypothetical deductive (scientific) reasoning within education, medicine, and PT. This literature review then briefly describes the role of technological scaffolds in assisting learners to solve ill-defined problems and the role of scaffolding in education and PT.

Reflecting these four strands of research, this literature review is divided into four sections. The first section, on scientific reasoning using a hypothetical deductive strategy and education, will present the approaches to support learning of the scientific (hypothetical deductive) reasoning process within education and its relationship to scientific (hypothetical deductive) clinical reasoning, definitions and epistemology of clinical reasoning and its relationship to scientific reasoning, as well as describe the progression of clinical reasoning with experience and the supportive factors necessary for increasing PT students' scientific clinical reasoning. The second section will explore the role of algorithmic frameworks, such as the HOAC II, in facilitating scientific clinical reasoning and clinical decision-making. The third section will consider the role of educational methods—including classroom-based approaches, computer-based media, and MT—in facilitating scientific (hypothetical deductive) reasoning and increased scientific clinical reasoning as understood within education, medicine, and PT. Finally, the fourth section will elucidate the role of technology-based educational scaffolds and their relationship to the educational process in PT education.

Scientific (Hypothetical Deductive) Reasoning, Clinical Reasoning, and Educational Approaches to Facilitating Clinical and Scientific Reasoning

Teaching individuals to solve ill-defined problems and reason scientifically and systematically is a concern for educators within the professions of education, physical therapy, and medicine. From these concerns, definitional and educational constructs to teach the processes of clinical and scientific reasoning have been identified. Subsequently discussed within this section will be the definitional constructs of scientific reasoning, educational strategies to develop scientific reasoning, the congruence between scientific reasoning and scientific clinical reasoning, definitional constructs of clinical reasoning, and educational processes utilized to support the development of scientific reasoning or clinical reasoning within the professions of education, medicine, and PT.

Scientific (Hypothetical Deductive) Reasoning: Definitions and Epistemology

Scientific inquiry or scientific reasoning education is often linked with teaching students to perform general reasoning or problem solving, including the abilities for students to apply cognitive skills and strategies to the process (Zimmerman, 2000). When defined in this way, students are taught to reason within hypothetical deductive reasoning process. This process, from a positivist epistemological stance (Duschl, 2008; Taylor & Medina, 2013), requires students to consider the problem at hand, articulate ideas or theories as to why the problem exists, generate theoretical constructs to test related to the problem, obtain data, recognize confirming and disconfirming data, reflect upon their process of thinking, and, finally, draw conclusions about causal factors that may relate to the problem at hand (Kuhn, 1993). The concern for development of these types of skills is to enable individuals to learn how to understand science and therefore be able to "generate and evaluate scientific evidence and explanations and participate productively in scientific practices and discourse" (Duschl, 2008, p. 269).

Because students need to develop skills to effectively engage in scientific discourse, the epistemology of scientific reasoning is important to consider. Considered within the teaching of scientific reasoning has been how students learn to effectively conduct scientific inquiry and solve complex problems. These factors have been considered from three different stances, the cognitive processes by which students learn, which includes the concepts, knowledge and processes used; the epistemology of the discourse that occurs when students are learning that includes the process or frameworks of reasoning, and the social mediation that takes place in the reporting of scientific discovery that includes how knowledge is represented, reflected upon, and articulated (Duschl, 2008, p. 269).

Scientific reasoning: development and supportive factors. Because of the three domains (cognitive, discursive, and social) involved in the scientific reasoning process, and the possible complexity of scientific problems, educators have been concerned with how to best develop scientific reasoning in students. Due to this concern, several authors have attempted to describe the development of scientific reasoning and hypothesis generation in those beginning to learn to reason as compared to expert scientists. Further described within the literature are supportive factors to teach students to scientifically reason using a hypothetical deductive process from the three domains. Each of these topics will be described subsequently.

Development of scientific reasoning from novice to expert. Within the scientific reasoning literature, there has been discussion of the development of scientific reasoning in those who are first learning the processes of scientific reasoning to those who are expert scientists. When individuals are first learning to reason, they do not always select appropriate experiments or systematic strategies to reason, do not draw correct inferences from data, do not develop rationales for their arguments, and do not spend as long collecting initial data (Schauble, 1996; Schunn & Anderson, 1999). Further complicating the scientific reasoning process, individuals who are learning to scientific reasoning often commit errors due to being set in prior beliefs, by becoming prematurely set in or fixed in a way of thinking, making incorrect interpretations about data collected, or misrepresenting the relevance of information to the scientific problem (Greenhoot, Semb, Colombo, & Schreiber, 2004; Schunn & Anderson, 1999). However, as expertise develops, the selection of strategies improves, domain specific knowledge increases, and errors decrease (Greenhoot et al., 2004; Schunn & Anderson, 1999). Finally, as individuals gain expertise they tend to propose more and better solutions, spend more time collecting data to inform the problem, and utilize new knowledge to inform the testing of hypotheses by employing reflection (Schunn & Anderson, 1999).

Factors that support scientific reasoning. Since scientific reasoning consists of complex processes, the identification of other supports or factors necessary for facilitating effective scientific reasoning in students and scientists, besides expertise, have been of interest. As individuals are reasoning, they require several abilities considered within the cognitive and discursive context of scientific reasoning to successfully solve ill-defined complex, scientific problems. These discursive ability for individuals to reason has been related in the literature to procedural knowledge, and the cognitive context of reasoning has been related to declarative knowledge (Lawson, 2004). From a procedural knowledge stance, individuals must have the ability to use a mental strategy or process for collecting data, which may include the ability to collect and organize data, prevent errors by employing flexibility in thinking, incorporate data sources into the reasoning process, follow a heuristic or algorithmic process, make decisions with incomplete data, and derive different conclusions when confronted with new data sources (Duschl, 2008; Glaser, Schauble, Raghavan, & Zeitz, 1992; Lawson, 2004; Zimmerman, 2005; Zimmerman, 2000). From the declarative knowledge point of view, scientific reasoning is supported best by having a comprehensive, domain-specific knowledge base (Lawson, 2004; Zimmerman, 2005).

An additional factor that has been proposed to facilitate scientific reasoning, is ability for the student to reflect upon the process and results of the decision-making process, from the perspective of the social context of scientific reasoning. This social context of scientific reasoning allows individuals to explain their findings, generate new arguments, and improve their ability to develop defensible knowledge claims (Duschl, 2008). Without using the process of reflection, individuals are less likely to be able to solve problems, examine diverse perspectives, link their findings to evidence, and correct mistakes (Kim & Hannafin, 2011).

Clinical Reasoning: Definitions and Epistemology

The process of scientific clinical reasoning within the healthcare environment, from some perspectives, can be considered to be congruent to the mechanisms utilized with scientific reasoning, in that a hypothetical deductive process is utilized (Kaufman, Yoskowitz, & Patel, 2008; Patel et al., 2005; Terry & Higgs, 1993). Similar also to education, clinical reasoning using a hypothetical deductive (scientific) or narrative reasoning process, has been widely defined and studied in the profession of physical therapy and medicine. The rationale for discussing both PT and medicine within this section of the literature review is twofold. First, a congruence of reasoning strategies exists between these two professions. Secondly, when comparing PT with medicine or education, there is a paucity of literature on the use of educational strategies, computer-based, or mobile-based technologies for facilitating scientific clinical reasoning.

Within the PT profession, Terry and Higgs (1993) define clinical reasoning as “the complex thinking and decision-making processes associated with generating clinical hypotheses that become clinical practice” (p. 47). Other authors in the PT profession have included other concepts in their definitions of clinical reasoning: the clinical decisions reached based upon the data collected; the cognitive process of deliberation about an appropriate course of action within a specified clinical context; the clinician’s process of reflecting on activities to arrive at a diagnosis; or narrative reasoning which focuses on the strategies used to manage patient care based upon knowledge, patient goals, patient belief systems, and professional judgement (Edwards et al., 2004; Smith, Higgs, & Ellis, 2008a; Smith, Higgs, & Ellis, 2008d; Terry & Higgs, 1993; Wainwright et al., 2010; Wainwright, Shepard, Harman, & Stephens, 2011). In contrast to PT, the process of clinical reasoning in medicine is more focused on establishing an initial diagnosis and treatment plan and is less focused on follow-up care and continued patient management (Higgs, 1992). However, it is claimed that the schemas used and supports needed for clinical reasoning are similar between the two disciplines (Patel et al., 2005; Payton, 1985).

Similar to scientific reasoning, many complex processes have been said to occur during clinical reasoning in both PT and medicine. These processes, which practitioners engage in while face-to-face with patients presenting clinical problems, have been defined within both medicine and PT. Definitions stem from either a positivist epistemology, a constructivist epistemology, or from a stance that incorporates the two (Edwards, et al., 2004; Patel, et al., 2005).

In the positivist epistemology, reasoning is focused on the generation of hypotheses related to diagnosis of the patient (scientific clinical reasoning). Within this hypothetical deductive process, which is similar to the process that occurs with scientific reasoning, clinicians focus on a stepwise process which consists of “attending to initial cues, forming tentative hypotheses, analyzing patient information, collecting more data, interpreting new data, and re-evaluating hypotheses (reflecting on decisions made)” (Edwards et al., 2004, Patel, et al., 2005, Payton, 1985). Throughout this process, valid, replicable, and reliable data and evidence are important as guides to inform decision-making (Edwards, et al., 2004; Patel, et al., 2005). This positivist epistemology also encompasses the development of procedural schema or heuristic framework that guides reasoning (Patel, et al. 2005; Higgs & Hunt, 1999; Payton, 1985). An example of this schema or heuristic framework within clinical reasoning is the use of pattern recognition, where an individual recognizes case features based upon previous experiences with similar patients and pursues a singular hypothesis in their reasoning process (Patel, et al. 2005; Higgs & Hunt, 1999; Payton, 1985).

In contrast to the positivist approach, the constructivist epistemology of clinical reasoning focuses less on the generation of hypotheses. Instead, it emphasizes the use of narrative processes between the patient and the clinician, using their values and belief systems, or the patient’s lived experiences of pain and illness, in order to guide interventions and outcomes (Edwards, et al., 2004). Combining the two stances, some researchers in medicine and PT have emphasized that reasoning in practitioners is dialectical in nature, including both patient experiences (narrative clinical reasoning) and the processing of data that leads to hypothesis generation and diagnosis (scientific clinical reasoning) (Edwards et al., 2004; Patel, Kaufman, & Kannampallil, 2013).

Since clinical reasoning consists of complex processes situated within a complex healthcare environment, the identification of supports or factors necessary for facilitating effective clinical reasoning in medical or PT students and practitioners has been of interest. Several authors have attempted to describe the development of clinical reasoning and hypothesis generation in students or novice and expert practitioners, as well as the domains and factors that constitute and influence clinical reasoning and hypothesis generation, or the process of generating a diagnostic hypothesis (Boshuizen & Schmidt, 1992; May, Greasley, Reeve, & Withers, 2008; Patel et al., 2013; Wainwright et al., 2010). Each of these factors has been studied with the goals of improving both PT education and practice and provide perspectives essential for supporting appropriate educational strategies for facilitating the growth of clinical reasoning and hypothesis generation in medical and PT students.

Clinical Reasoning: Development and Supportive Factors

In considering how to develop clinical reasoning through educational interventions in PT and medicine, it is important to first understand that similar to scientific reasoning, clinical reasoning and hypothesis generation develops on a continuum as domain specific knowledge and skills are developed; for this reason, these faculties also differ between novice and expert practitioners (Doody & McAteer, 2002; Jensen, Gwyer, Shepard, & Hack, 2000; May et al., 2008; Payton, 1985; Rothstein et al., 2003; Smith et al., 2008; Smith, Joy, & Ellis, 2010; Wainwright et al., 2010; Wainwright et al., 2011). Within physical therapy, studies have demonstrated that compared to novices, experts tend to utilize more succinct reasoning schemata such as pattern generation, revert to hypothetical deductive reasoning strategies when confronted with challenging problems, tend to be more confident in their clinical decisions due to their knowledge base and experience, and use reflection during their evaluation processes and after their evaluation processes to shape clinical decisions (reflection in and on actions taken) (Embrey, Guthrie, White, & Dietz, 1996; Hendrick, Bond, Duncan, & Hale, 2009; Jensen et al., 2000; Wainwright et al., 2010). In contrast, novice physical therapists and PT students often have difficulty formulating and evaluating hypotheses and once they have gathered subjective and objective sources of information from the patient; they also tend to use less reflection during the course of examination and treatment, and tend to be less confident (Wainwright, et al., 2010; Doody & McAteer, 2002; Gilliland, 2014; Hendrick, Bond, Duncan, & Hale, 2009). Further complicating the generation of hypotheses, novice practitioners and PT students may use less effective reasoning strategies such as trial and error, may gather too much data by conducting a "plethora of tests," may "suspend hypothesis generation until all data are collected," or may "not have enough experience or knowledge to generate a hypothesis to focus their evaluation strategies" (Gilliland, 2014; Rothstein, Echternach, & Riddle, 2003, p. 463).

Similar to scientific reasoning, another distinguishing factor in clinical reasoning between novice and expert PT practitioners is that expert practitioners tend to commit less errors as they are performing patient assessment, congruent to findings in the education literature on the development of scientific reasoning. The reason for this is multifactorial including the fact that the cognitive process used with expert clinical reasoning is more refined. In contrast, novice practitioners clinical reasoning process is less refined and therefore, novice practitioners tend to commit more errors while clinically reasoning. Congruent to the scientific reasoning literature, these errors may be linked to becoming prematurely set in or fixed in a way of thinking (anchoring), making incorrect interpretations, or misrepresenting the relevance of information (commission bias) (Croskerry, 2002; Croskerry, 2003; Grant, 2008).

Similar findings about the role of expertise on clinical reasoning and hypothesis generation have been found within medicine. Patel et al. (2013) state that experts and novices make dramatically different decisions that are informed by different reasoning strategies. Strategies used by novices in medicine tend to rely more on extensive data collection and be less focused, whereas strategies utilized by experts tend to rely more on pattern recognition and be more focused. These differences are hypothesized to occur due to the effects of experience: years of clinical practice bring greater knowledge organization, increased domain-specific expertise, and the ability to utilize prior experiences to inform practice (Boshuizen & Schmidt, 1992; Patel et al., 2005; Patel et al., 2013).

Factors that support clinical reasoning. In addition to considering clinical expertise as a factor in clinical reasoning, other factors have been identified that support efficient and effective clinical reasoning and hypothesis generation in medicine and PT. Smith et al. (2008) have classified these factors in four domains: cognitive, reflective, emotional, and social. Each of these domains will be discussed next, with the emotional and social domains considered together.

Within the cognitive domain of clinical reasoning, also known as scientific clinical reasoning, several factors have been identified that are essential for supporting reasoning and hypothesis generation. Among these factors, which are congruent within scientific reasoning, medicine and PT, are the following: the ability to collect data in an organized manner, prevent medical/other errors, process multiple sources of data, follow a procedural schema or decision-making pathway, confirm or deny hypotheses, make decisions in the presence of uncertainty, and adjust decisions as new information is presented (Patel et al., 2013; Smith et al., 2008). Another factor included in both in the cognitive domain of scientific reasoning and clinical reasoning is a patient-centered, well-organized, accessible, comprehensive, relevant, and accurate knowledge base (Terry & Higgs, 1993; Jensen et al., 2000).

An additional factor that has been proposed to facilitate scientific clinical reasoning and hypothesis generation, within medicine or PT, in congruence with scientific reasoning, is the reflexive ability of the student or practitioner. These activities are based upon the work of Schön (1987), which focused upon the practitioner's use of reflection-on-action and reflection-in-action. Reflection-in-action is concerned with the dynamic processes that occur within the patient encounter, which allow the individual to react to an uncertain event and change tactics (Patel et al., 2005; Schon, 1984; Wainwright et al., 2010). In contrast, reflection-on-action is the ability to draw from experience and change future actions based upon past successes or failures (Wainwright et. al., 2010). Each of these forms of reflective practice is seen to decrease medical error, as well as contribute to the refinement of clinical reasoning processes of students and practitioners within both medicine and PT (Jensen, 2000; Patel et al., 2005; Wainwright et al., 2010).

Finally, in addition to the cognitive and reflective domains, two other domains are also considered necessary to facilitate clinical reasoning and hypothesis generation: the emotional and social domains, more related to narrative clinical reasoning. Within these domains are the awareness of self-efficacy; the capability to deal with stressful situations; the motivation to learn; an understanding of the patient's views; and the ability to interact with, learn from, and involve others in one's reasoning processes (Smith et al., 2008). Each of these factors within the emotional and social domains are mentioned more frequently within the literature in PT, nursing, and occupational therapy, and less frequently in medicine (Edwards et al., 2004). The presence of these factors within the clinical reasoning literature evolved as a reaction to the predominance of the positivist, hypothetical deductive, scientifically-oriented reasoning factors found within the medical literature (Edwards et al., 2004). These factors are equally important to the other factors mentioned previously, as they are theorized to be essential to promote dialectical or conditional reasoning, which considers both stances of reasoning, scientific and narrative. From this approach, dialectical or conditional reasoning focuses on the interplay among data collection, ethical judgments, and the negotiation of understandings among the therapist, other practitioners, and the patient, and thereby ensures deep integration of all factors pertinent to patient care (Edwards et al., 2004; Jensen, 2000).

Building on the knowledge that clinical reasoning and hypothesis generation develop on a continuum and are reliant upon multiple factors, educators in PT and medicine have identified key constructs essential to facilitating clinical reasoning and hypothesis generation in students. They have done so by incorporating both scientific and narrative clinical reasoning domains into educational practice. The most important constructs involved in scientific clinical reasoning, which are often emphasized within curricula, are posited to be the cognitive components of acquiring skills and knowledge, and the development of psychomotor skills (Terry & Higgs, 1993). However, the other domains of clinical reasoning also need to be developed within students in order to promote sound clinical reasoning and hypothesis generation (Higgs, 1992; Terry & Higgs, 1993). Focusing on these other constructs, multiple authors have cited the need for increased pedagogical focus on other components within scientific clinical reasoning, including teaching students how to process data using decisional pathways or algorithmic frameworks, form hypotheses, and recall and organize knowledge (similar to those emphasized with scientific reasoning). Furthermore, it is posited that educators need to increase the number of educational opportunities to develop students' abilities within both the reflexive (related to scientific clinical reasoning) and social domains (related to narrative reasoning): within the reflexive domain by encouraging reflection-in-action and reflection-on-action, and within the social domain by incorporating patients' values and understandings in order to improve patient outcomes as students transition into clinical practice (Grant, 2008; Higgs, 1992; Higgs & Hunt, 1999; Kaufman et al., 2008; Patel et al., 2005; Patel et al., 2013).

The HOAC II, Algorithmic Frameworks, and Clinical Reasoning

Since novices and physical therapy students demonstrate greater difficulties with scientific reasoning and clinical reasoning related to formulating reasoning strategies than do experts, some researchers have suggested that patient and scientific reasoning outcomes can be improved through the use of different methodologies to organize and structure (scaffold) scientific reasoning or scientific clinical reasoning, such as algorithmic frameworks (Glaser et al., 1992) Evidence within the medical and education literature demonstrates that algorithmic processes based upon the hypothetical deductive model of reasoning, when used with scientific clinical reasoning or clinically to support decision-making about patient diagnoses and plans of care, can increase: the practitioner's organization of knowledge, depth of scientific reasoning or scientific clinical reasoning, and incorporation of evidence from multiple sources (Demetriadis et al., 2008; Patel, Arocha, Diermeier, How, & Mottur-Pilson, 2001; Rothstein et al., 2003).

Given the evidence within the scientific reasoning and medical literature about the efficacy of algorithmic frameworks to shape scientific reasoning or scientific clinical reasoning using a hypothetical deductive model of reasoning, Rothstein, Echternach, and Riddle (2003) posited the Hypothesis Oriented Algorithmic Framework II. This framework was based upon the scientific, hypothetical deductive reasoning process postulated by Payton (1985). Rothstein et al. (2003) theorized that the use of this framework would allow the PT clinician or student to utilize a process of sequential clinical reasoning and hypothesis generation to improve four key aspects of patient care: patient problem definition from data derived or inferred from the patient, patient problem management from diagnostic hypotheses generated, the management of chronic conditions, and the use of evidence to guide practice (Rothstein, Echternach & Riddle, 2003).

Within the HOAC II algorithmic framework, Parts I and II, data collected from the patient and other sources of information are used to assist in developing hypotheses that guide the evaluative, diagnostic, and treatment processes associated with patient care. Part I of the HOAC II (HOAC II-1) framework is centered on the steps in the evaluative framework as presented in the Guide to Physical Therapist Practice (American Physical Therapy Association, 1999). The five steps are as follows: examination, defined as the scientific collection of data from the patient through evaluative tests and measures; evaluation, which includes disconfirming or confirming hypotheses generated from outside consultation and the examination process; integrating and synthesizing information from examination and evaluation to generate a series of diagnostic hypotheses; selecting the most appropriate hypothesis by synthesizing information from examination and evaluation; and finally, formulation of a prognosis that includes the plan of care. Within this framework, the plan of care includes four considerations: anticipated (future) patient problems that exist as a result of present problems; preventative measures to impact future impairments or disability; current problems related to impairments or functional disability that require immediate intervention; and documentation of expected improvements from the plan of care (American Physical Therapy Association, 1999, p. S35; Rothstein et al., 2003). Part II of the HOAC II framework consists of re-assessment of problems or reexamination, defined by the Guide to Physical Therapist Practice as “the process of performing selected tests and measures after the initial examination to evaluate progress and to modify or redirect interventions” (APTA, 1999, p. S39). This definition is broadened within the HOAC II framework to include a redefinition and re-evaluation of diagnostic hypotheses generated using outcome measures to document interventions and outcomes (reflection on action), thereby ensuring treatment appropriateness and optimal treatment results (Rothstein, et al., 2003).

Within PT, the benefit of an algorithmic framework such as the HOAC II is congruent to the scientific reasoning and medical literature. It has been suggested that the HOAC II supports scientific clinical reasoning in several ways: by scaffolding the sequence of decisional processes, deepening reasoning processes, organizing information collected, and assisting in the consideration of all factors in the decisional process through promotion of reflection. Research by Kenyon (2013) demonstrated that by using the HOAC II framework with students, modified for application to pediatrics, PT educators were able to provide students with a “consistent and systematic method” for organizing the evaluative processes and therefore “ensure[d] that all aspects of the examination or intervention session were considered and carried out” (p. 419). Congruent findings were also found from using the HOAC I framework to support scientific clinical reasoning, which uses a similar structure for clinical reasoning to the HOAC II (Wessel, Williams, & Cole, 2006). These authors found that the HOAC I model, when used with PT students on a first clinical rotation, helped students to “think about what they were doing and why they were doing it” (p. 5). The model also assisted them in “identifying omissions in their assessment, treatment, or reasoning” (p. 8). Finally, research by Gilliland (2014) found that the integration of external frameworks in PT curricula with first-year students, similar to the HOAC II, allowed them to better scaffold the reasoning process and utilize a more sophisticated strategy of clinical reasoning, which included consideration of both present and anticipated future problems.

Some support does exist for the use of the HOAC II within clinical settings. Within the hospital environment, a study reported that this model was used successfully with a cystic fibrosis patient on bedrest; the model was used to prevent anticipated problems for the patient (possible future impairments), which allowed the maintenance of mobility and decreased the risk of pressure ulcers, thereby improving the long-term outcomes of the patient (Lowman, Kirk, & Clark, 2012). Another study that used a similar framework of anticipating patient problems, using hypothetical reasoning and the amelioration of problems pertaining to current disability, found a decrease in mortality and morbidity in patients who were post-cardiac surgery (Afilalo et al., 2011).

Educational Strategies to Facilitate Scientific Reasoning or Clinical Reasoning in Education, PT, and Medicine

In addition to the use of algorithmic frameworks to shape scientific reasoning, and PT and medical students' scientific clinical reasoning abilities in classroom and clinical settings, researchers have also emphasized the need for sound pedagogies to teach scientific reasoning and scientific clinical reasoning. This emphasis has been important because of the need to equip students to scientifically reason in order to transfer these complex problem-solving skills into real life activities, and to equip students in PT and medicine with the ability to clinically reason in all domains as they enter practice. These domains have been taught in scientific reasoning and in both PT and medical student practice using multiple methodologies, including classroom-based, computer-based, and mobile-based approaches, each with its own benefits for facilitating scientific reasoning or clinical reasoning. These modes of delivery will be discussed in the following sections, along with research that supports their ability to facilitate the specific domains of clinical or scientific reasoning.

Classroom-Based Methodologies to Support Scientific Reasoning

Classroom based methodologies to support scientific reasoning evolved due to the complex nature of scientific reasoning that required more than just knowledge support facilitated through traditional lecture experiences. With the profession of education, the emphasis on experiential learning using actual (genuine) experimentation, problem-based learning, and case-based learning have been suggested as more effective strategies for facilitating learning of the domains of scientific reasoning (Zimmerman, 2005). Research within educational context has demonstrated that these more authentic learning experiences increase individuals' ability to form scientific arguments, develop domain specific knowledge, use better procedural heuristic schema, engage in reflection about the scientific process, and make better conclusions from evidence collected (Duschl, 2008; Glaser et al., 1992; Lawson, 2004; Zimmerman, 2005; Zimmerman, 2000).

Classroom Based Methodologies to Support Clinical Reasoning

Congruent to education, classroom-based methodologies to facilitate clinical reasoning evolved in response to the inadequacy of traditional lecture-based pedagogies to develop domain-based contextual clinical or scientific reasoning competencies, apart from the task of imparting knowledge (Higgs, 1992; Kaufman, et al., 2008). Instead of utilizing traditional lecture, Terry and Higgs (1993) advocate for the use of self-directed learning strategies, problem-based learning, discussion, reflective exercises, and case-based learning as strategies for facilitating adequate clinical reasoning in all domains. Coherent to studies on scientific reasoning, multiple studies in medicine and PT have demonstrated that these strategies provide advantages over traditional lecture in that they allow students to develop the ability to generate diagnostic hypotheses, understandings of the knowledge, increased expertise in knowledge application, the ability to reason conditionally and dialectically, flexibility in knowledge retrieval and use, and the ability to translate classroom knowledge and experiences into the clinical context (Higgs, 1992; Higgs & Hunt, 1999; Kaufman et al., 2008; Nelson, 2010).

Computer-based Methodologies to Facilitate Scientific Reasoning

Computer based strategies within education evolved to teach scientific reasoning in an effort to present consistent pedagogy and andragogy for educational experiences in an effort to increase the authenticity of learning (Millis et al., 2011). These computer-based strategies mirror those used in the classroom used to teach scientific reasoning, by presenting authentic problems through case based, experiential, and problem-based activities. Several studies within education have identified that computer based teaching methodologies can support the process of scientific reasoning by: making the thinking process explicit, scaffolding the reasoning process through decisional frameworks, allowing individuals to manage the process of scientific investigation, increasing integration of knowledge, improving problem solving abilities, allowing access to needed information thereby increasing discipline specific knowledge, and improving recognition of patterns within the data to improve hypothesis generation and scientific conclusions (Brush & Saye, 2002; Edelson, Gordin, & Pea, 1999; Min, Chuang, & Yu-Shiang, 2010).

Computer and Technology-Based Methodologies to Facilitate Clinical Reasoning

Similar to education, the advent of computer-based technology for facilitating clinical reasoning evolved from successful classroom-based practices used to teach clinical reasoning strategies. Computer-based interventions in PT and medicine were developed for teaching clinical reasoning and hypothesis generation in order to address the inadequacy of classroom activities for teaching learners who were located at multiple practice sites in diverse geographic locations (Grant, 2008). Further, computer-based instruction enabled educators to standardize the presentation of material and cases essential for practice. An additional benefit to computerized instruction was to allow students to develop expertise by increasing exposure and experience with clinical practice through engagement with the same or different cases multiple times; with standard classroom-based instruction, such varied engagement is not typically possible (Grant, 2008; Huhn et al., 2013).

In both PT and medicine, computer-based learning, or e-learning, has been defined by researchers as the use of synchronous or asynchronous instruction using computer-based media to teach concepts essential to practice (Grant, 2008; Koshmahl, 1994). These media have included, but are not limited to, high-fidelity human patient simulation, virtual cases, video, live patient interaction with telemedicine, web-based instruction using learning management systems such as Blackboard or Moodle, blogging for reflection, and asynchronous discussion boards (Veneri, 2011). As computer-based technologies have evolved, researchers in medicine and PT have explored how they may provide external supports for the domains and process of clinical reasoning and hypothesis generation.

Medical education has developed a focus on the cognitive and reflective domains of clinical reasoning when employing computer-based technology, while largely neglecting the social and emotional domains. However, due to this focus, the use of computer-based technology in medicine and medical education for facilitating the cognitive domain of clinical reasoning (scientific clinical reasoning) by organizing information and scaffolding hypothesis generation has been well established. Patel et al. (2013) cite the benefits of computer-based health information technology in assisting this domain by “mitigating some of the cognitive load by acting as cognitive aids, by supporting decisions and reasoning through decisional pathways, and by providing organizational structures for health information” (p. 166-167). More specifically, a study found that a researcher-generated decisional support system used to scaffold reasoning in clinical settings, tested using a randomized controlled trial, increased physicians' diagnostic performance, hypothesis generation, and clinical reasoning by providing the information and organization of knowledge needed at point of care (Friedman et al., 1999).

Another methodology that has been utilized successfully within the clinical setting as a decisional support for the cognitive domain of clinical reasoning in medicine is computerized order entry (CPOE). CPOE provides an order-entry algorithm for common procedures and medications within medical practice (Patel et al., 2013). In interventional study, an algorithmic CPOE system was effective in improving care quality and decisions related to managing and reducing risk factors related to falls within the nursing home environment (Colón-Emeric et al., 2009).

Other studies in medicine have focused specifically on the use of case-based methodologies for facilitating the cognitive domain of clinical reasoning (scientific clinical reasoning) by presenting multiple cases to increase experience, and therefore increasing pattern recognition. In a systematic review of the literature, this methodology for teaching clinical reasoning was found to have been more effective than no intervention. Further, in a study on facilitating knowledge and pattern recognition in medical students, no difference in educational outcome was found between computer-based case presentations and traditional educational methodologies (Cook et al., 2010).

In contrast to medical education, most of the physical therapy research on computer-based instruction has focused solely on the ability of computer-based media to facilitate the cognitive components of clinical reasoning (consisting of knowledge and psychomotor skills necessary for PT practice), and upon the comparison of this delivery strategy to classroom-based techniques (Veneri, 2011). When compared to standard classroom strategies, these studies have found little to no differences in the knowledge retained or the ability for students to perform psychomotor tasks following interventions using computer-based media (Dennis, 2003; Ford, Mazzone, & Taylor, 2005; Murray, McCallum, & Petrosino, 2014; Smith Jr, Jones, Cavanaugh, Venn, & Wilson, 2006). Further, no empirical studies have emphasized the use of decisional supports in the clinical setting. However, a few studies within PT have explored the use of computer case-based methodologies to facilitate the cognitive components of clinical reasoning (related to the processes of scientific clinical reasoning or generating hypotheses), and another study has researched the use of using blogging to facilitate the cognitive, social and reflexive components of clinical reasoning. These studies will be discussed below.

Research within physical therapy that has addressed the use of computer case-based methodologies to facilitate clinical reasoning has not focused on using an algorithmic framework in combination with a clinical case. Instead, studies have primarily focused on the use of computer media in the implementation of case-based andragogy to advance skills within the cognitive domains of clinical reasoning (scientific clinical reasoning). Huhn et al. (2013) created a computer-based system that focused on case-based learning using simulated patients and used a mixed-methods approach to compare this computer-based system to traditional, classroom-based methods. The quantitative methodologies found no difference between the two student groups' ability to reason on a standardized measure of clinical reasoning; however, in the qualitative portion of the study, students identified that they had improved within the cognitive domains of clinical reasoning (scientific clinical reasoning). Students cited improved clinical reasoning skills, increased efficiency of reasoning, and the ability to utilize pattern recognition a reasoning strategy.

Another study using case-based methodology was conducted by Seif et al. (2013). This study utilized a pre-test, post-test design to determine the effects of a sequential, clinically based case, presented through Moodle, a learning management system. Improvements from this intervention were found from pre- to post-test in the cognitive (scientific clinical reasoning) domains of seeking data, comparing and contrasting information, planning the examination strategy, and hypothesizing reasoning for problems, as well as using experience, or pattern recognition, as a form of clinical reasoning.

Finally, a study by Bayliss and Warden (2011) utilized a hybrid instructional approach (computer- and classroom-based) for facilitating clinical reasoning abilities using a problem-based learning methodology with a post-test evaluation. Within this study, the impact on clinical reasoning was described as increased ability to engage in “higher-order thinking” (p. 14) due to effects on the cognitive (scientific clinical reasoning) domain of clinical reasoning; however, direct effects of the singular use of computer-based instruction could not be determined (Bayliss & Warden, 2011).

In addition to full case-based or problem-based methodologies to affect clinical reasoning, researchers have also studied the effect of blogging on PT students’ clinical domains of reasoning during clinical placement (Tan, Ladyshewsky, & Gardner, 2010). In a qualitative analysis of blog posts, the authors found that all domains of clinical reasoning could be promoted, and that students were more likely to demonstrate conditional reasoning as they reflected in writing their blog posts. Within the cognitive (scientific clinical reasoning) domain, students were able to reason about the sequence or procedures of reasoning, and within the reflective domain, students engaged in reflection on actions taken within the clinical settings. Finally, within the social and emotional domains, students were able to engage other students to help with reasoning processes; they were also able to reason about ethical issues related to practice, as well as engage in dialectical, conditional reasoning between data and patient emotional and social factors.

Mobile Technology Based Methodologies to Support Scientific Reasoning in Education

Within the literature, the use of mobile technology (MT) to facilitate the learning process is denoted as mobile learning, or m-learning. M-learning has been described as using a portable device such as a PDA or mobile phone for e-Learning (Ally, 2009; Premkumar, 2011). M-learning differs from computer-based or e-learning in that it is personal, situated in the learner's context and location, available everywhere, integrated with daily activities, and portable (Kukulska-Hulme & Traxler, 2005). Specifically, it can be used to place information at an appropriate time to influence cognitive processes (just in time), in the location where it is needed, and on-demand (Premkumar, 2011, citing Barneveld & Shaw, 2006).

Within the profession of education, the use of MT to support scientific reasoning in higher education is scant, however demonstrates promising results in supporting learning. Within the literature, the use of MT for scientific reasoning has been focused upon using mobile technology to collect data, draw observations about data, and promote personalized experiential learning. The use of MT in experiential learning focused on scientific reasoning has been shown to increase engagement with the learning process, allow learners to seek domain specific knowledge when needed, promote engagement with domain specific knowledge as conclusions are drawn, and allow learners to better articulate their rationales (Song, Wong, & Looi, 2012). A further study focused upon experiential learning, scientific reasoning, and data collection demonstrated that MT was able to increase the ability of learners to integrate data obtained from the mobile application into scientific understanding and increase domain specific knowledge acquisition. Also posited within this study was that learners were best supported in learning of the scientific reasoning process when procedural based scaffolds were applied to assist learners in engaging in problem identification and articulation of rationales for the conclusions drawn through the provision of substantive evidence (Land & Zimmerman, 2015).

Mobile Technology Based Methodologies to Support Clinical Reasoning in Medicine and Physical Therapy

Due to the success of computer-based programs and supports to facilitate scientific reasoning and clinical reasoning in PT and medicine, and the emerging success of MT in facilitating scientific reasoning (m-learning) within education, healthcare researchers have begun to explore the utility of MT for teaching clinical reasoning, due to the features described above. Similar to education, these devices provide affordances for situated learning at the bedside and therefore may foster PT and medical student learning in the clinical environment.

Taking advantages of the affordances provided by m-learning as noted above, medical educators and practitioners have used MT to facilitate the cognitive domain of clinical reasoning by allowing information retrieval to build knowledge and providing just-in-time information about patient conditions. Chang et al. (2012) found, in a qualitative case study, that mobile learning in the remote environment of Botswana assisted physicians in the cognitive domain of knowledge by enabling them to access necessary point-of care information. This study also found support for the utility of MT to promote self-directed knowledge acquisition (Chang et al., 2012). Further, two studies using intervention-based methodology, found that medical students who used mobile devices to access just-in-time point-of-care information in the clinical setting were able to gain support for the cognitive domain of knowledge, thus benefiting from MT in their development of clinical reasoning (Davies et al., 2012; Johnston et al., 2004).

Another use of MT within medicine is clinical logging software, which assists students in developing in the cognitive domain of sequencing processes as well as in the reflexive domain of clinical reasoning. In these ways, the software helps improve future decisional processes, hypothesis generation, and pattern recognition. At least two studies have demonstrated positive results from this form of m-learning. The authors of these intervention-based studies determined that the use of mobile clinical logging software allowed students to engage in reflection-in-action by recording and reflecting on the sequence of clinical reasoning and clinical problems that are encountered during patient interactions; they were also able to engage in reflection-on-action by reviewing these logs and identifying gaps in knowledge or decisional strategies and taking action to correct them (Coulby et al., 2011; Luanrattana, Win, Fulcher, & Iverson, 2012).

At present, the literature on m-learning within PT is limited. No literature yet exists on the use of MT to scaffold scientific clinical reasoning processes using algorithmic frameworks or to support hypothesis generation in PT. However, two studies are available that support the use of mobile learning to facilitate the social domain and cognitive domain of clinical reasoning (scientific clinical reasoning), including knowledge and skill acquisition in the clinic. The first study, found that MT was able to support knowledge acquisition, was utilized to educate others, and provided social connection to others (Tilson, Loeb, Barbosa, Jiang, & Lee, 2016). The second study within PT that discusses MT, describes facilitation of the social and knowledge domains of clinical reasoning within the clinical setting in PT. In this study, the authors provided an iPad to PT and OT students on clinical rotations, and through qualitative inquiry, found that the devices facilitated the activities of patient communication, just-in-time information needed for patient care, research, collaboration with colleagues, and information-sharing (Arinola & Clouder, 2015).

Other studies within PT education have focused solely on the use of mobile application development of the cognitive domain of clinical reasoning that supports scientific clinical reasoning, in ways that are specific to the development of psychomotor skills and knowledge within the classroom and laboratory setting. The authors of these studies have cited positive learning effects that support the use of mobile applications to facilitate psychomotor skill acquisition in learning musculoskeletal special tests (Hoglund, 2015); to develop the anatomical knowledge needed for safe practice when performing manual therapy techniques (Noguera, Jiménez, & Osuna-Pérez, 2013); and to gain knowledge of foundational science (Kojima, Mitani, & Ishikawa, 2011).

The Role of Scaffolding in the Educational Technology Environment and its Relationship to Physical Therapy

Scaffolding within education in classroom and educational technology contexts has been described as "expert support for a novice's learning" (Sharma & Hannafin, 2007). This support may be defined as a means to move a learner who is developing certain problem-solving skills like clinical or scientific reasoning, to a higher level of problem solving, initially by providing explicit instruction, followed by decreasing supports (scaffolds) as the learner becomes more independent (Bruning et al., 1999). Within technology enhanced environments, the technology functions to provide expert-based scaffolding to support cognitive tasks such as managing cognitive load or metacognitive processing (Sharma & Hannafin, 2007). These scaffolds may be provided in a fixed, or non-negotiable manner (hard), or in a contextually sensitive or on-demand (soft) manner, similar to the supports provided by a clinical instructor at the point of care (Sharma & Hannafin, 2007).

Further presented within education is a guideline for CAL to facilitate complex problem solving (scientific reasoning) using a hypothetical-deductive strategy (Quintana et al., 2004). This guideline advocates for methodological design to scaffold computer aided learning modules (CAL) to best manage learning the complex process of scientific reasoning and decision making using technological media. Within this guideline, the hypothetical deductive process of scientific decision making (reasoning), which is similar to the process of PT scientific clinical reasoning, is defined by three domains: sense making, process management, and reflection and articulation. Sense making within the model directly relates to the steps the learner goes through in hypothetical reasoning, specifically, generating hypotheses, making comparisons, collecting observations, analyzing data, and interpreting data. The second domain, process management, relates to the cognitive load tasks that the learner has to perform when making decisions such as keeping track of hypotheses, data, and results and the organizational strategies that the learner employs such as algorithmic frameworks. Finally, the last domain, articulation and reflection, relates to the process of providing metacognitive support for helping the learner to articulate their thought processes, guide the thought process, and allow the learner to reflect upon decisions made.

By using CAL scaffolding to support these three domains of hypothetical-deductive (scientific) reasoning within hypermedia environments, studies within education have shown positive effects. Effects cited within the literature on learning have included an increased ability to: plan and choose a strategy for problem solving, seek knowledge support and gain knowledge through provided scaffolding, monitor the process of decision making through reflection and metacognition, engage more deeply with content, successfully engage in more efficient and effective discipline-related decision-making, and formulate hypotheses and solutions to problems

(Azevedo, Cromley, & Seibert, 2004; Brush & Saye, 2002; Quintana et al., 2004). These effects are primarily demonstrated when the CAL learning environment is highly structured (uses a problem framework) and focuses upon the cognitive and metacognitive processes of solving ill-defined problems (Azevedo, Cromley, & Seibert, 2004.) Further support is also found for scaffolding scientific reasoning using case-based contexts in supporting the articulation of problem focused process, eliciting recall of information, and improving ability to problem solve when different case contexts were presented (Demetriadis et al., 2008). Within the medical education literature, congruent effects have also been shown when scaffolding is applied to case-based contexts in CAL in that improves and facilitates the process of diagnostic reasoning and making differential diagnoses (medical problem solving) (Jonassen, 1996). However, these studies, while successful in supporting the domains and process of scientific reasoning, do not use MT in combination with algorithmic frameworks and case-based approaches.

In contrast to the profession of education and medical education, within the profession of PT education, very few articles exist on the impact of scaffolding in classroom or clinical contexts. Of those that do exist, their focus is narrowly constructed, imparting data related to skills involved in the scientific clinical reasoning process, such as the development of the psychomotor domain of knowledge, or on the clinical instructor's facilitation of clinical reasoning related to structuring the reasoning process through sense making to make thinking evident. Within the classroom, the role of scaffolding has been described as being successful in providing expert guidance and support by providing visual cues as perceptual scaffolds to facilitate psychomotor processes, or in utilizing graphics as a media to help with articulation of how to perform psychomotor tasks (Rose, 1999). In the clinic, research has been conducted related to teaching CI's to formulate a thinking routine to scaffold student's clinical reasoning by making thinking evident. The authors of this article found when CI's taught students a thinking framework and made the disciplinary thinking strategy evident, that it allowed students to justify clinical judgements, explain their reasoning, and improved their ability to distinguish amongst different diagnoses (Delany & Golding, 2014).

While success has been found in the limited literature from PT education in classroom and clinical contexts for scaffolding scientific clinical reasoning, the literature is non-existent for CAL and MT within PT. Therefore, this is an area of needed study within PT. However, based upon the fact that scientific clinical reasoning resembles scientific reasoning in a lot of ways, it is reasonable to hypothesize similar results from using scientific reasoning scaffolds such as sense making, process management, and reflection and articulation, in scaffolding clinical reasoning hypermedia (MT and CAL) to support the hypothetical deductive reasoning process that occurs in PT.

Conclusion

Many modes of educational delivery have been used to facilitate scientific reasoning or clinical reasoning in education, PT, and medicine, including classroom-based, computer-based, and mobile-based approaches. Further, within medicine and PT researchers have explored and validated the role of algorithmic frameworks, such as the HOAC II-1 or CPOE systems, and their influence on clinical reasoning. Within the professions of medicine and education, the literature is well established for the use of algorithmic frameworks, or classroom, computer, or mobile-based methods to teach the cognitive domains of clinical reasoning. In the PT and education professions, congruent with medicine, the role of classroom-based methods and algorithmic frameworks are also well established.

Conversely, in contrast to medicine, the literature on computer-based or mobile methodologies using case-based approaches or case-based approaches in combination with an algorithmic framework to teach or clinical reasoning in physical therapy is in its infancy. Further, the support for the role of CBT or MT that integrates algorithmic frameworks to support and scaffold clinical reasoning within PT is lacking, and therefore requires study. Therefore, this study investigated how MT using a scaffolded mobile application facilitates higher order clinical reasoning strategies, the sequence of clinical reasoning, and what scaffolds PT student-participants learning clinical reasoning most rely upon. The next chapter, Chapter 3, describes the instructional design of the mobile application under study, in order communicate the intentionality used in structuring the mobile application to facilitate scientific clinical reasoning.

CHAPTER THREE: APPLICATION DESIGN

For the purposes of this study, a mobile application was designed using the ADDIE framework model of instructional design, which is an iterative design model that consists of analysis, design, development, implementation, and evaluation (Davidson-Shivers & Rasmussen, 2006, p. 54), in order to form a developmental andragogy for facilitation of the process of scientific clinical reasoning in physical therapist (PT) students. This chapter describes the first three steps in the instructional design framework (analysis, design, and development).

Initial Analysis of the Problem and Application Design of the Mobile Application

Described subsequently in this section are the first two steps of the ADDIE model, analysis and design. Using the researcher's experiential knowledge, an analysis was conducted in order to identify the problems that PT students commonly have when reasoning clinically. Three problems were identified in students' clinical reasoning: inability to organize data into a framework that allows hypotheses to be developed, inability to generate hypotheses from data collected, and inability to select appropriate tests to confirm or deny hypotheses. A further problem that was identified was a lack of access to just-in-time knowledge support while working with patients in the clinic or, alternatively, while working with a partner in the classroom during laboratory sessions consisting of tests and measures, pathologies, and treatment strategies. Interestingly, the problems identified by this researcher in her own clinical practice with PT students are also congruent with the literature in development of scientific reasoning and scientific clinical reasoning.

Therefore, considering the researcher's personal experiences, the literature pertaining to the development of scientific clinical reasoning in PT students, the capabilities of mobile devices to support learning, the capabilities provided by computer-based algorithms in supporting scientific reasoning and scientific clinical reasoning, and the possible benefits of providing a scaffolded mechanism to facilitate learning of scientific clinical reasoning for PT students, a solution was proposed that involved the use of a mobile application to support scientific clinical reasoning. This solution was designed by first defining the major goal of the mobile application: to provide a cross-platform mobile solution that employed three scaffolding principles (sense making, process management, and reflection and articulation) to assist PT students in structuring the decisional processes that occur while performing scientific clinical reasoning with an actual patient or practice case in order to improve the strategies and sequence of scientific clinical reasoning.

Design Considerations

Once the major goal of the application was defined, the design process commenced. There were three important considerations in the design process, namely, 1) the ability for the application to cross platform, 2) the ability for the application to be used in the classroom or clinic, and 3) the ability for the application to integrate learner centered design to support scientific clinical reasoning using scaffolding. These considerations will be discussed subsequently.

First, it was important to consider how the mobile application could be used on different mobile devices that were currently available in the marketplace including laptop computers, tablet computers, and mobile phones, all of which had different operating systems. Therefore, a consideration was made as to which programming language and database would effectively cross-platform, and therefore, enable use of the application on all mobile devices, laptop computers, and tablet computers. Choosing a cross platform solution was considered important as it prevented individuals from having barriers to learning from a lack of access to a particular operating system. Therefore, HTML-5 was selected as the programming language and jQuery mobile databasing was utilized for structuring the database for the scaffolding objects, as they both function on all currently available operating systems.

A second important consideration in application design was the need to be able to use the mobile application in the classroom using a case-based context, or in the clinic or simulated clinical setting (using high fidelity human patient simulation or standardized patients). This consideration was of importance to design, to allow students to first practice using the mobile application with the case-based context and then subsequently, use the structure provided by the mobile application to assist with reasoning in the clinic or simulated clinical experience. Therefore, the mobile application was developed with both of these options, with the case-based part of the application (explored in this study) and a part of the application that could be used in the clinic (to be explored in a subsequent study). However, both designs utilized similar methodologies for navigation and data entry. An example of the ability to select between case based and clinic use modes is noted in Figure 3.1, below, from the developed application.

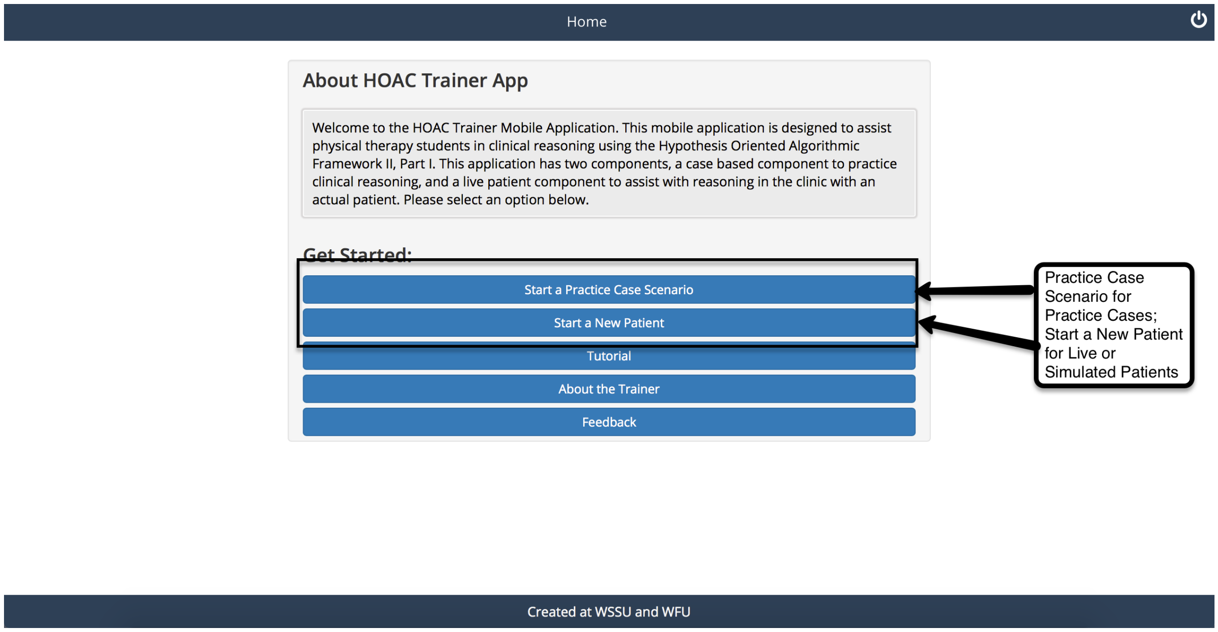


Figure 3.1. Case Based or Live Patient Selection Option

The third and final consideration in designing the mobile application was learner centered design to allow the mobile application to effectively support scientific clinical reasoning. Considering the challenges that PT students have when performing scientific clinical reasoning and the support provided by scaffolding for process of scientific reasoning, a process for learner centered design of the mobile application was implemented. This meant that the application was designed according to the recommendation of Quintana et. al. (2004), citing Scardamalia and Breiter (1991), that learners were provided with an intentional learning framework (via the mobile application) that encouraged them to “articulate their understandings [pertaining to scientific clinical reasoning] through structured discourse” (p. 339). This resulted in two conceptual frameworks being identified to support learning the process of scientific clinical reasoning, the HOAC-II-1 and the Scientific Reasoning Framework Model. Both models were integrated into the mobile application, and are detailed subsequently.

First, a scientific clinical reasoning framework was identified within PT that was able to structure and provide an explicit scaffold to the process of clinical reasoning: the HOAC II-1. Within application design, this framework provided a disciplinary based, algorithmic structure to the scientific reasoning process (a structured discourse). By using the framework in this way, it was possible to make the disciplinary strategy apparent for learners through the use of application features or buttons designed into the mobile application. Table 3.1, below, describes the application feature or button designed into the mobile application, the application action taken when the application feature or button is accessed, and the part of the HOAC II-1 framework that is supported with the application action, feature, or button.

Table 3.1. Application Features and HOAC-II-1 Framework Supported.

Application Feature/Button	Application Action	Framework Supported
Scenario (pre-built)	Application provides initial data to student	Collecting Initial Data
Application popups “What is your rationale”	HOAC not followed in order	Supports sequence of HOAC II process
Patient History	Application provides a link to information about information to be gathered within the patient history	Supports knowledge needed for clinical reasoning
About HOAC	Application provides a link to information about the HOAC II framework	Supports knowledge about the HOAC II framework
About Conditions	Application provides a link to information about conditions covered by the application	Supports knowledge needed for clinical reasoning
About Tests	Application provides a link to information about tests needed to evaluate the patient problem	Supports knowledge needed for clinical reasoning
Hint	Application gives a hint about the next step in the evaluative process	Supports student in the process implementation of the stepwise framework of the HOAC II

Table 3.1. (continued).

Subjective Interview Button	Subjective Interview Button: Enter data from referral, case information given, observation, and subjective interview	Collecting Initial Data
Record Data Button	Generate Patient Identified Problems List: Application will ask the user to create a list of patient problems /symptoms to which the student can refer later, open text box for notes for problems/other items the student finds significant	Generate Patient Identified Problems List
Initial Hypothesis	Application will ask the user to input an initial working hypothesis and other hypotheses that are under consideration to be evaluated	Formulate Examination Strategy
Objective examination	Application will provide a list of possible tests based upon symptoms, help will be provided for knowing what the tests are, alternate symptoms, or other questions that they want to know the answer to.	Formulate Examination Strategy, Conduct the Examination
View results	Application will list positive and negative tests in summative form, symptoms that they looked for, patient identified problems, and hypotheses.	Refine Hypotheses, Carry out Additional Tests needed
Generate Problem List	Application will provide a list of patient and non-patient identified problems/ from tests allow user input of other detected problems; application will support user by giving a likelihood of diagnoses based upon inputs	Add non-patient Identified Problems
Final Hypothesis	Application will give a list of possible patient diagnoses, User will provide a rationale for selecting the diagnosis, ask for further non-patient identified problems, and for a treatment/referral decision and rationale	Generate a hypothesis, Refine Problem List

Further illustrating the integration of this framework are exemplars from the finalized application. These are presented as Figures 3.2, 3.3, 3.4, 3.5, and 3.6. Figure 3.2, below, demonstrates the scenario display page, pertaining to the initial hypothesis step in the framework. Figure 3.3, below, demonstrates support from the application provided through an application popup (soft scaffold) related to asking the student participant to provide a rationale for an out of order step taken during application use related to the sequence of the HOAC II-1 framework. Figure 3.4, below, demonstrates help features (soft scaffold) that are related to providing assistance while the mobile application is in use. These features either related to providing information about the HOAC II framework or knowledge support for clinical reasoning. Figure 3.5, below, demonstrates the Hint button (soft scaffold), which allows users to receive cueing for the next step in the framework that should be pursued. Finally, figure 3.6, below, depicts the buttons that pertain to the HOAC II-1 framework steps, which allow the user to proceed through the framework in an ordered manner, and permits access to a page to enter data pertaining to each step, on a screen specific to that step.

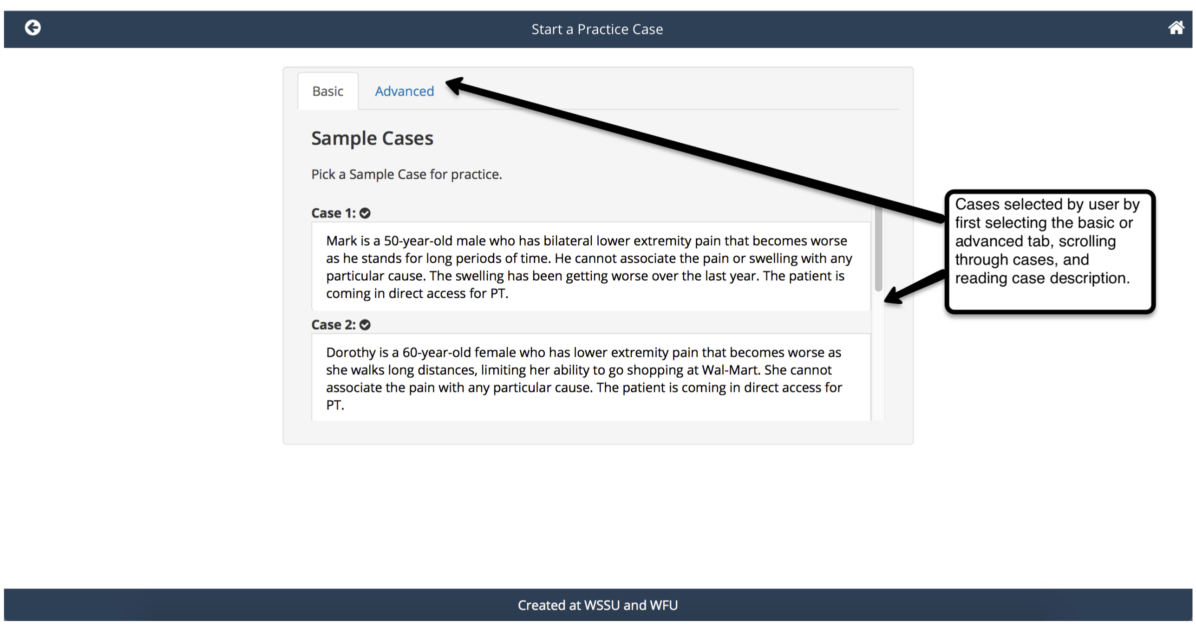


Figure 3.2. Scenario Selection Panel (Collect Initial Data).

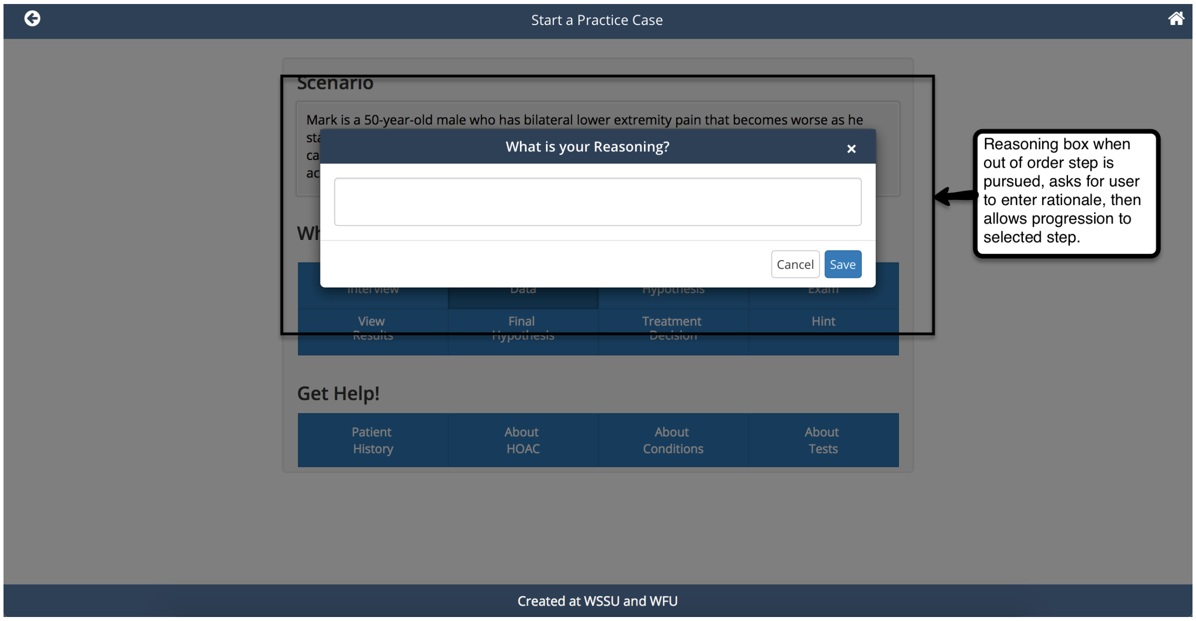


Figure 3.3. Out of Order Step Popup.

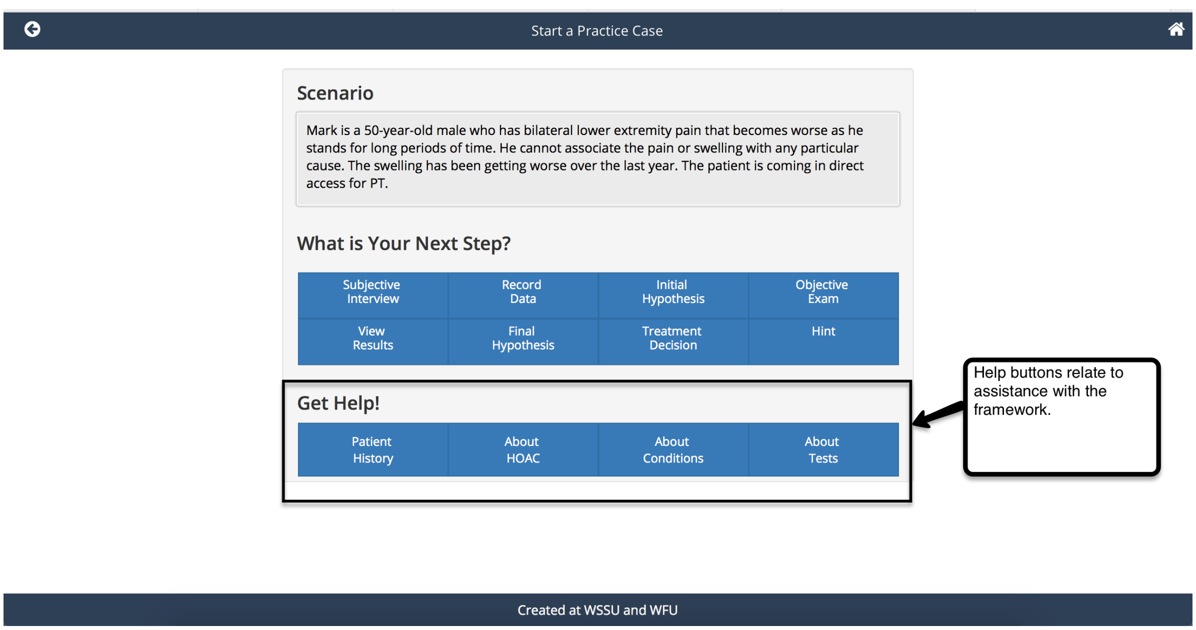


Figure 3.4. Help Buttons.

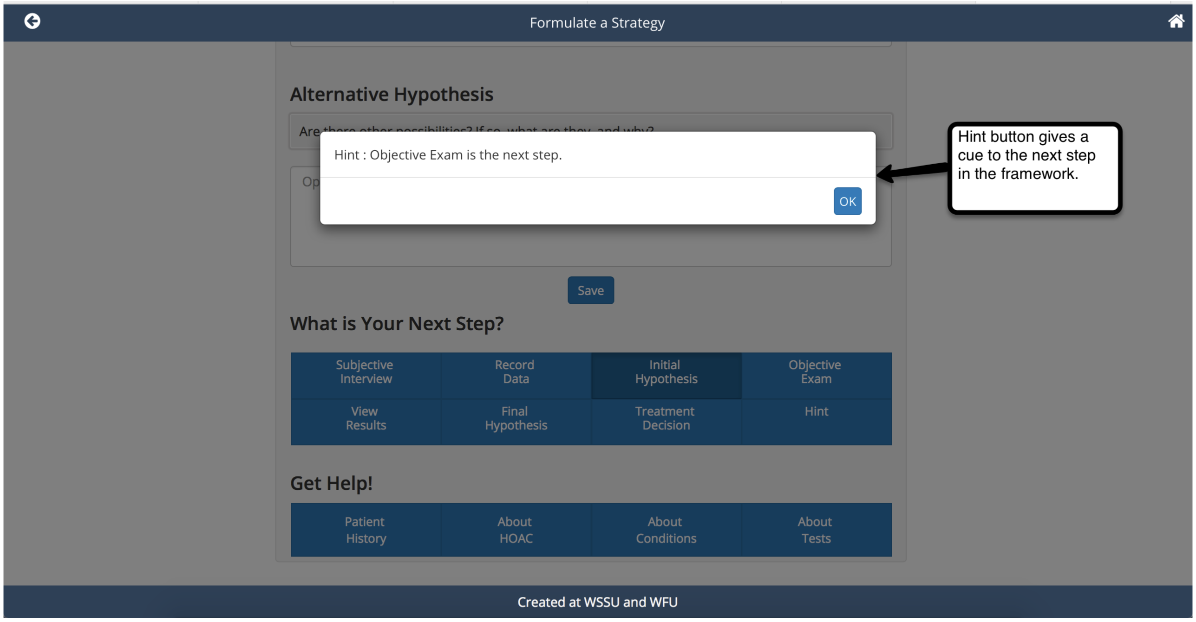


Figure 3.5. Hint Button.

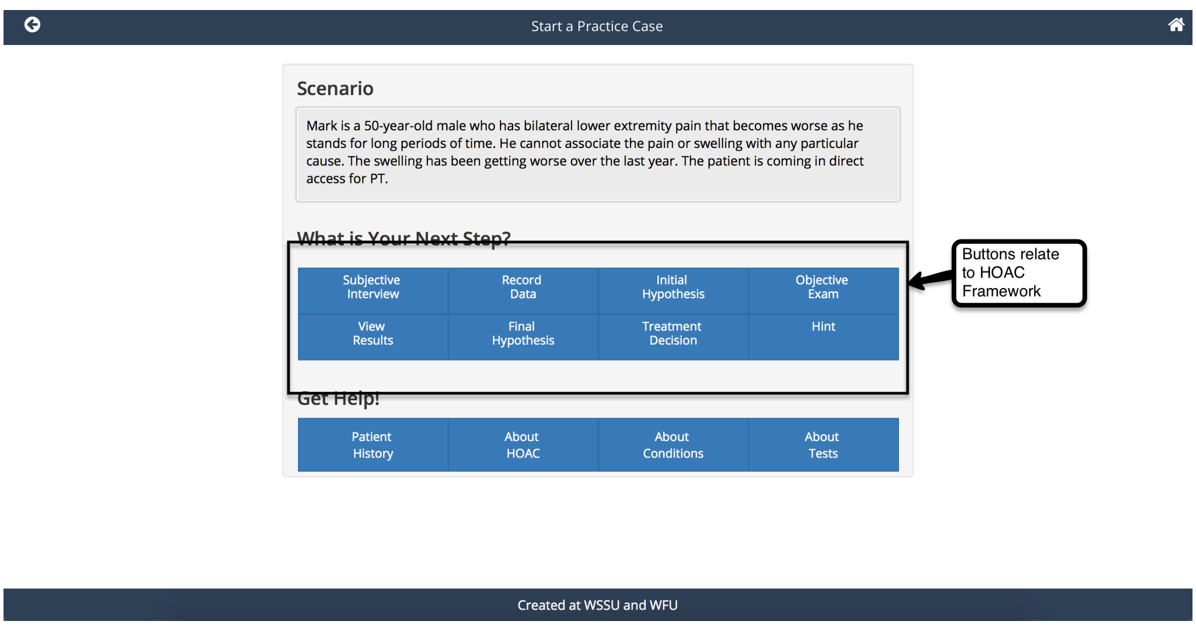


Figure 3.6. HOAC-II-1 Framework Buttons.

Secondly informing application design was a model that advocated for scaffolds needed to support scientific reasoning, posited by Quintana (2004). There were three reasons for choosing this model. First, this model was chosen and identified from the profession of education, since limited data exists on what scaffolds are needed to support scientific clinical reasoning in physical therapy. A second reason for choosing this scaffolding model is that scientific clinical reasoning and scientific reasoning follow similar processes. A third and final reason for using this model was to allow an investigation of what types of scaffolds are supportive for PT student scientific clinical reasoning in the implementation and evaluation steps of the ADDIE model, since this is a gap within the literature.

Use of this model informed the development of both hard (non-negotiable, ever-present) and soft (contextually-dependent or on-demand) scaffolds (Sharma & Hannafin, 2007). These scaffolds were constructed to support the tasks commonly performed by PT students when they are engaging in scientific clinical reasoning (sense making, process management, and articulation and reflection) (Quintana, et al., 2004). Table 3.2, below, describes how scaffolds present within the mobile application relate to the scaffolding framework model posited by (Quintana, 2004). Further relayed within the table are the types of scaffolding (hard vs. soft) (Sharma & Hannafin, 2007) utilized in technologically based environments as they pertain to the mobile application. In the first column, the application scaffolding features incorporated into the mobile application are described. These scaffolds utilize several elements from the scientific scaffolding design framework model posited by Quintana et al. (2004). In the table, the application scaffolding features are matched to the scaffolding design framework model in the next three columns, by relating them to the scientific inquiry component (sense making, process management, or articulation and reflection), the guideline that is addressed by that scaffold, and the scaffolding strategy utilized. In the final column of Table 3.2, the type of scaffold used, hard versus soft, as contextualized by Sharma and Hannafin (2007), is presented.

Table 3.2. Mobile Application Elements and the Scaffolding Design Framework Model (Quintana, 2004).

Application Feature	Scientific Inquiry Component	Guideline	Scaffolding Strategy	Type of scaffold (Sharma & Hannafin, 2007)
Buttons consistently identifying steps in the HOAC II-1 framework process	Process management	Guideline 6: Automatically handle non-salient, routine tasks. Guideline 4: Provide structure for complex tasks and functionality.	6c: Facilitate navigation among tools and activities. 4b. Decompose a complex task into its constituents using unordered task decompositions.	Hard
Cues to indicate out of order steps in the framework through popup when HOAC II-1 sequence is not followed.	Sense making	Guideline 2: Organize tools and artifacts around the semantics of the discipline.	2a. Make disciplinary strategies explicit in learner's interactions with the tool.	Soft
Reflection on steps taken out of order	Articulation and reflection	Guideline 7: Facilitate ongoing articulation and reflection.	7b. Provide reminders and guidance to facilitate productive monitoring.	Soft
Consistent application format	Process management	Guideline 6: Automatically handle non-salient, routine tasks.	6c: Facilitate navigation among tools and activities.	Hard
Help feature for "Patient History"	Sense making	Guideline 1: Use representations and language that bridge learner's understanding.	Guideline 1c. Embed expert guidance to help learners use and apply content.	Soft

Table 3.2. (continued).

Debriefing provided using expert guidance	Sense Making: Science inquiry component	Guideline 5: Embed expert guidance about scientific practices.	5a: Embed expert guidance to clarify characteristics of scientific practices.	Hard
"Hint" button	Sense making	Guideline 1: Use representations and language that bridge learner's understanding. Guideline 2: Organize tools and artifacts around the semantics of the discipline.	1c. Embed expert guidance to help learners use and apply content. 2a. Make disciplinary strategies explicit in learner's interactions with the tool.	Soft
Help feature for "About HOAC"	Sense making	Guideline 1: Use representations and language that bridge learner's understanding.	Guideline 1c. Embed expert guidance to help learners use and apply content.	Soft
Help feature for "About Tests"	Sense making	Guideline 1: Use representations and language that bridge learner's understanding.	Guideline 1c. Embed expert guidance to help learners use and apply content.	Soft
Limited condition set with data queries including: subjective questions, tests, patient problems, and diagnoses	Sense Making	Guideline 2: Organize tools and artifacts around the semantics of the discipline	Guideline 2a. Make disciplinary strategies explicit in learner's interaction with the tool (access to relevant data choices)	Hard
Help feature for "About Conditions"	Sense making	Guideline 1: Use representations and language that bridge learner's understanding.	Guideline 1c. Embed expert guidance to help learners use and apply content.	Soft

Table 3.2. (continued).

Arrows beside tests in objective examination screen that, when tapped, links the user to information about that test.	Sense making	Guideline 1: Use representations and language that bridge learner's understanding.	Guideline 1c. Embed expert guidance to help learners use and apply content.	Soft
Opportunity to provide reflections on end result given on (last) debriefing screen: "How can you improve for next time?"	Articulation and reflection	Guideline 7: Facilitate ongoing articulation and reflection.	7b. Provide reminders and guidance to facilitate articulation during sense making.	Hard
Textual instructions that explain the scientific practice in each step.	Sense Making: Science inquiry component	Guideline 5: Embed expert guidance about scientific practices.	5a: Embed expert guidance to clarify characteristics of scientific practices.	Hard
Opportunity to provide rationales/justify decisions offered during different points in the HOAC framework, including identifying their hypotheses and alternate hypotheses, formulating a strategy	Articulation and reflection	Guideline 7: Facilitate ongoing articulation and reflection.	7c. Provide reminders and guidance to facilitate productive monitoring.	Hard
Opportunity to provide notes on thoughts with data collection screen as evaluation is being planned, identifying other questions to ask after articulating the hypothesis, and identifying other symptoms for which they are looking during the examination.	Articulation and reflection	Guideline 7: Facilitate ongoing articulation and reflection.	7a. Provide reminders and guidance to facilitate productive planning.	Hard

Table 3.2. (continued).

Opportunity to provide a rationale for the final diagnostic hypothesis achieved and treatment decision.	Articulation and reflection	Guideline 7: Facilitate ongoing articulation and reflection.	7c. Provide reminders and guidance to facilitate articulation during sense making.	Hard

Further explaining design of these scaffolds are figures 3.6 through figures 3.11. These figures, from the finalized mobile application, illustrate using exemplars, the three types of scaffolds utilized in the mobile application: hard and soft scaffolds for sense making (Figures 3.7, 3.8, 3.9, and 3.10), a hard scaffold for process management (Figure 3.11), and hard scaffolds (Figure 3.12) for articulation and reflection.

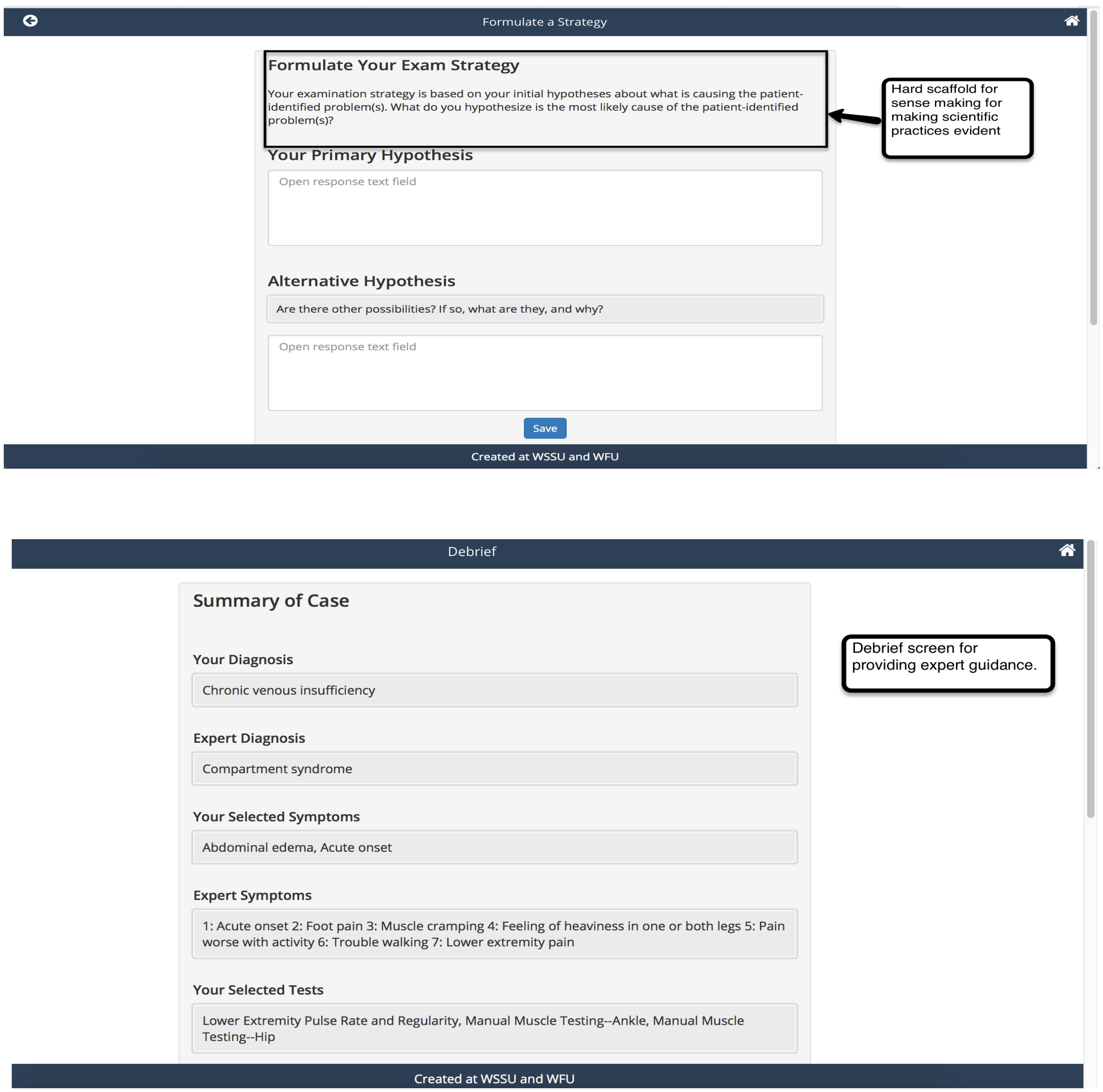
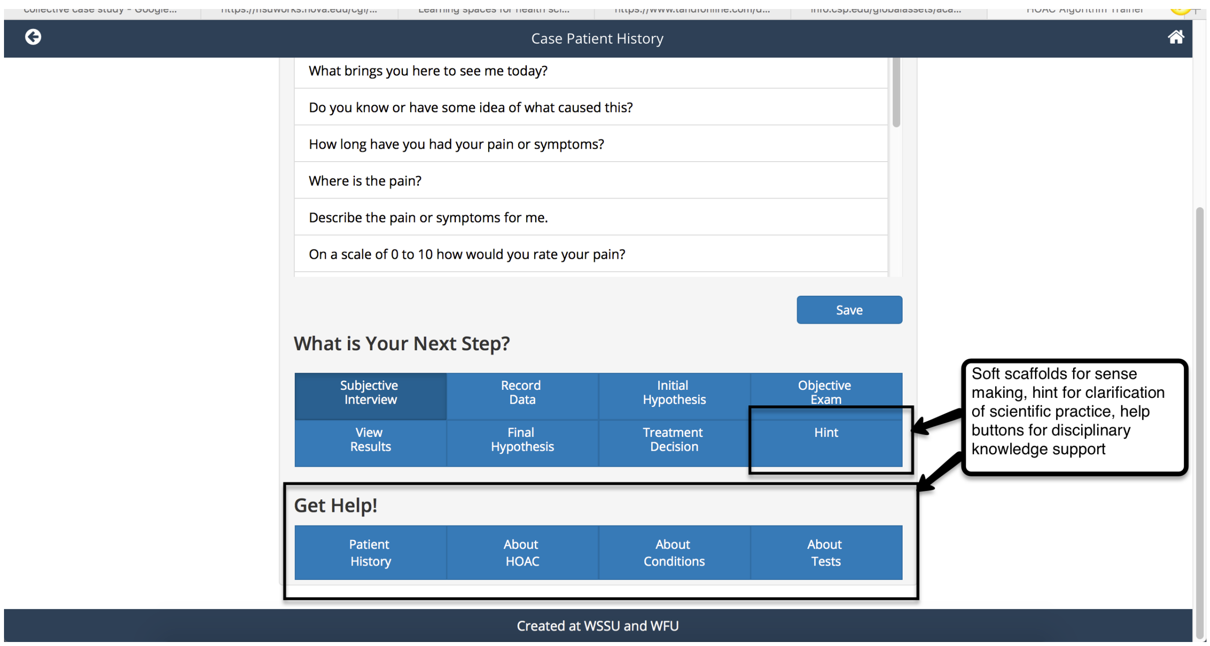


Figure 3.7. Sense Making Hard Scaffolding.



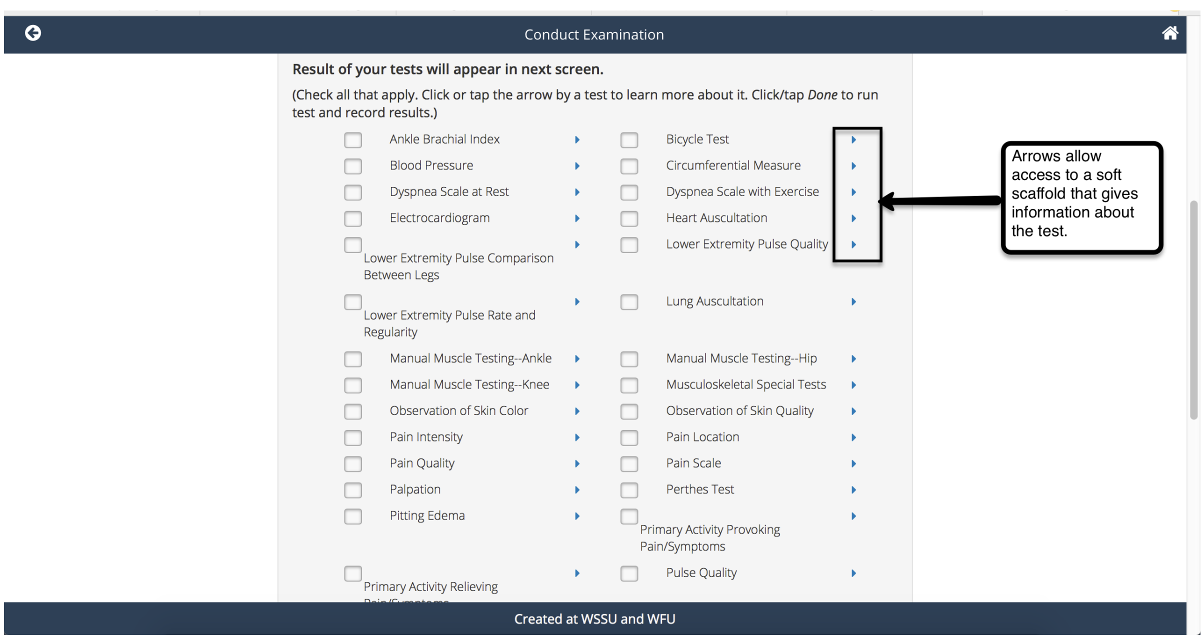


Figure 3.8. Sense Making Soft Scaffolds in the Mobile Application.

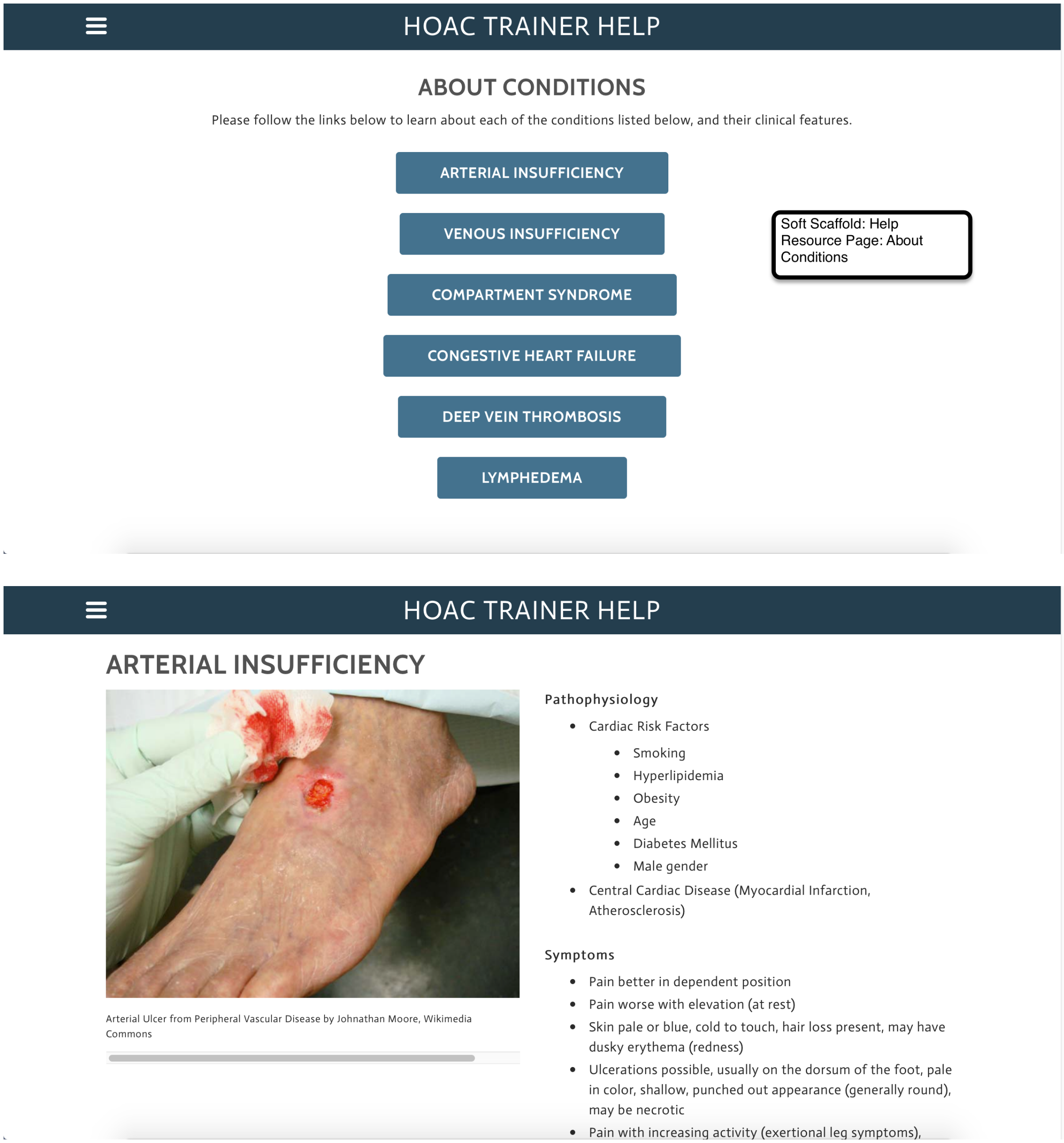


Figure 3.9. Sense Making Soft Scaffold: Help for About Conditions Access Screen and Exemplar.

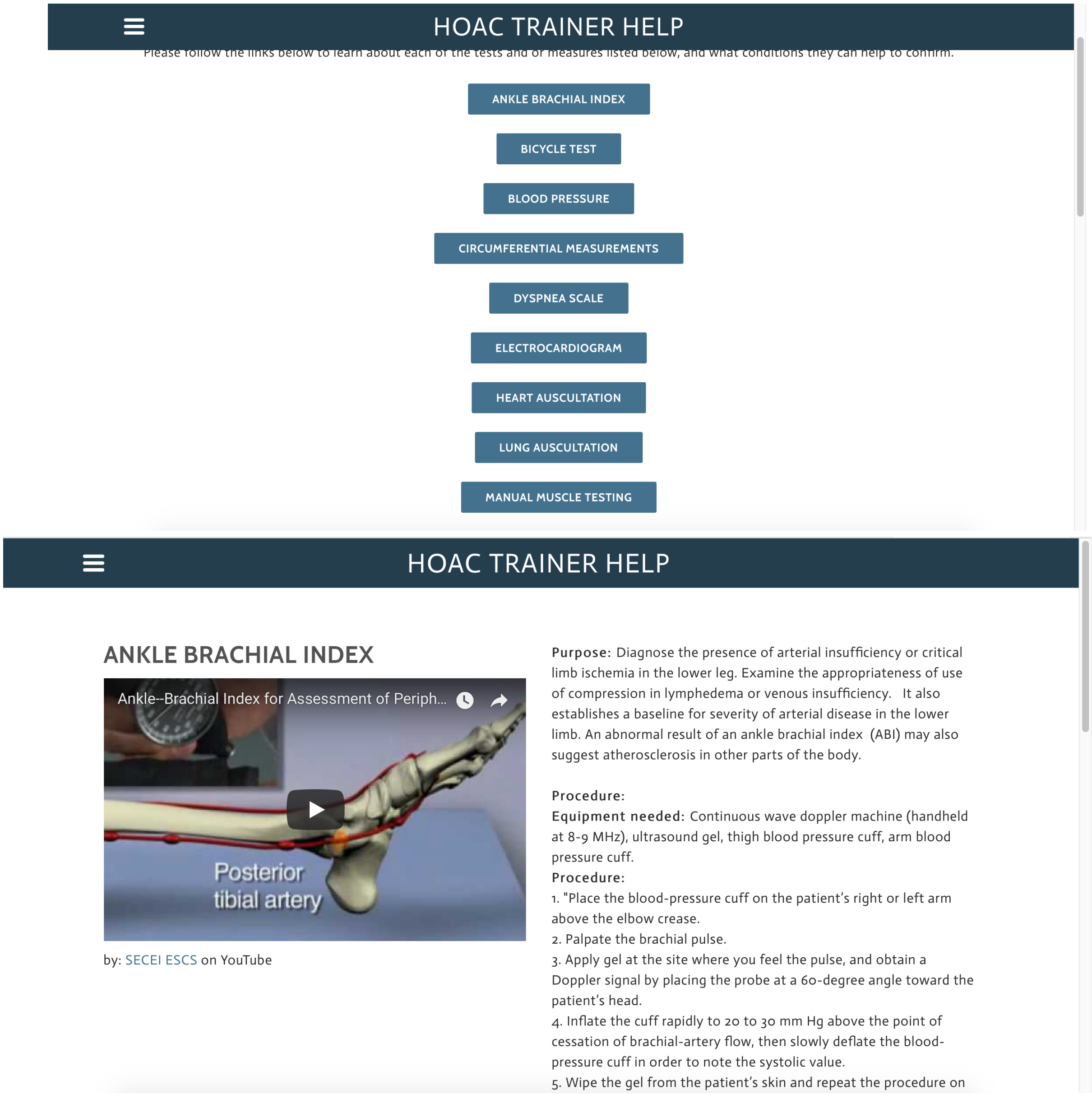


Figure 3.10. Sense Making Soft Scaffold: Help for About Tests Access Screen and Exemplar

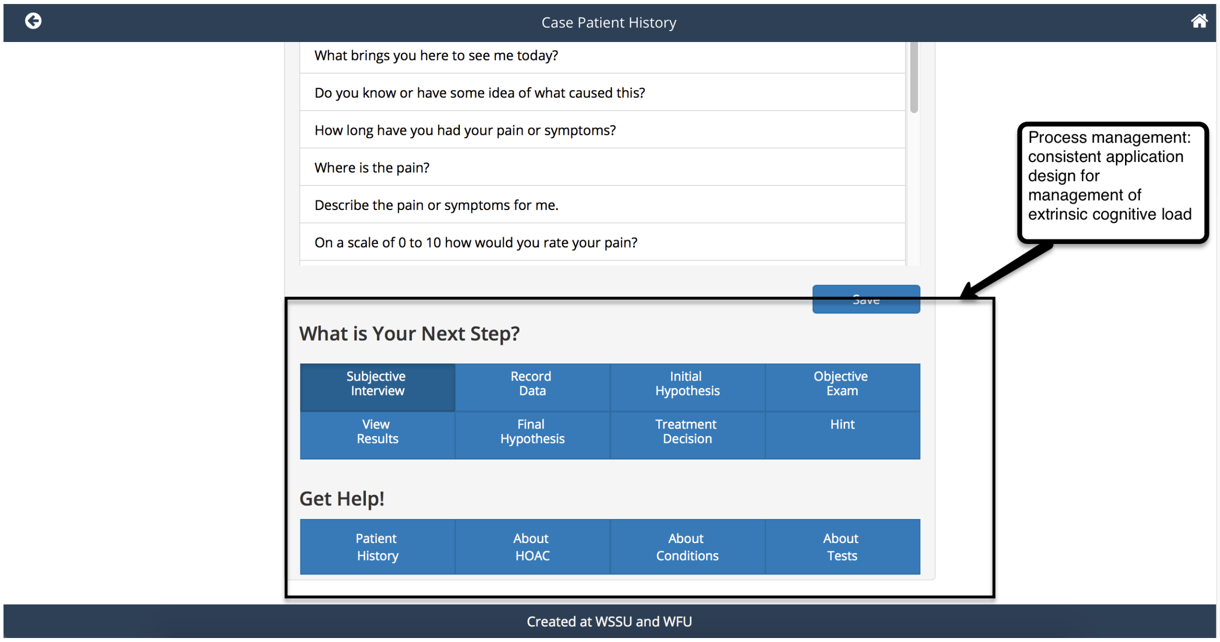
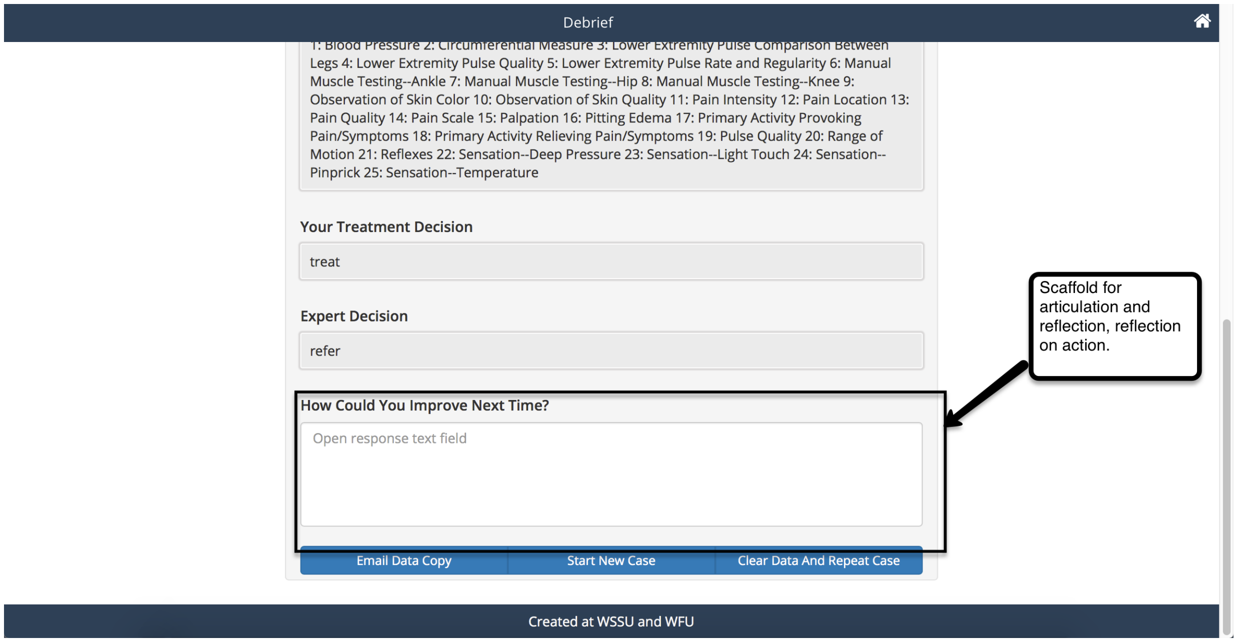


Figure 3.11. Process Management Hard Scaffold.



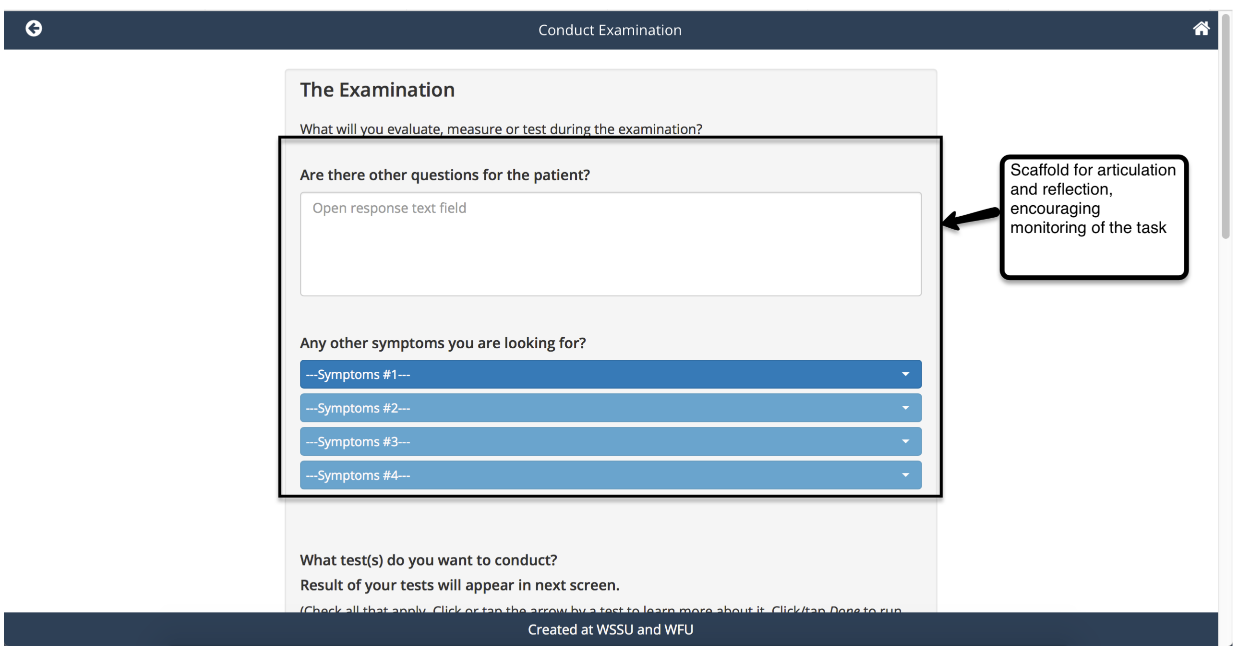
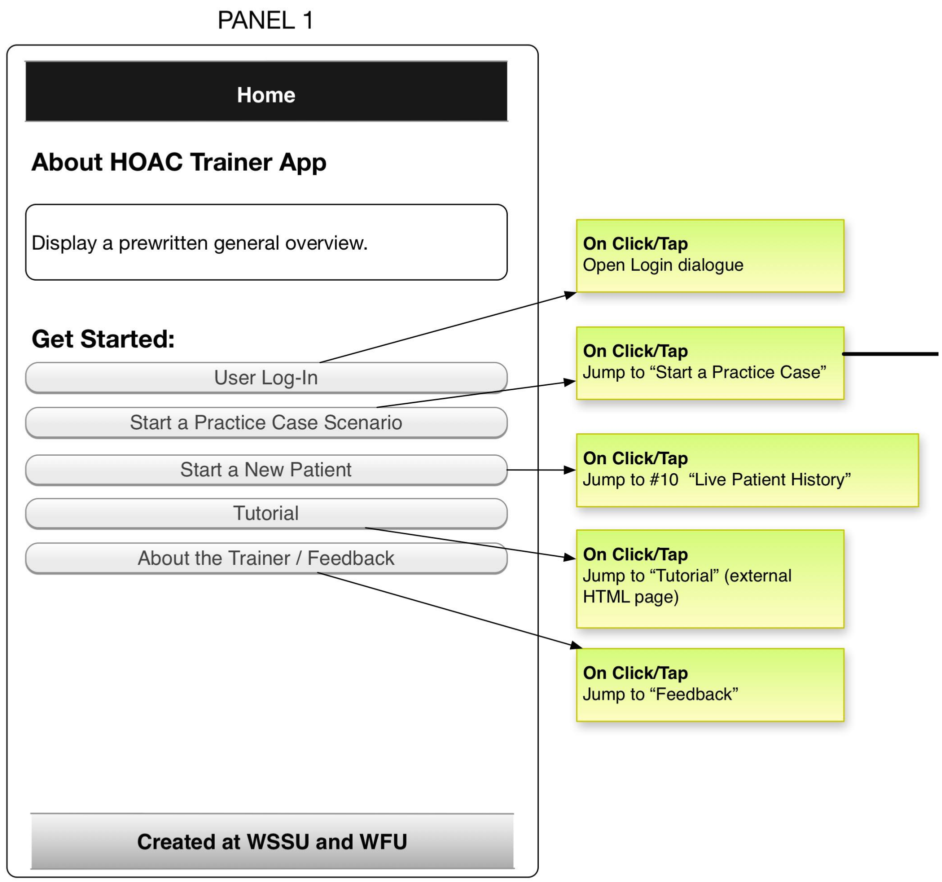


Figure 3.12. Articulation and Reflection Hard Scaffolds.

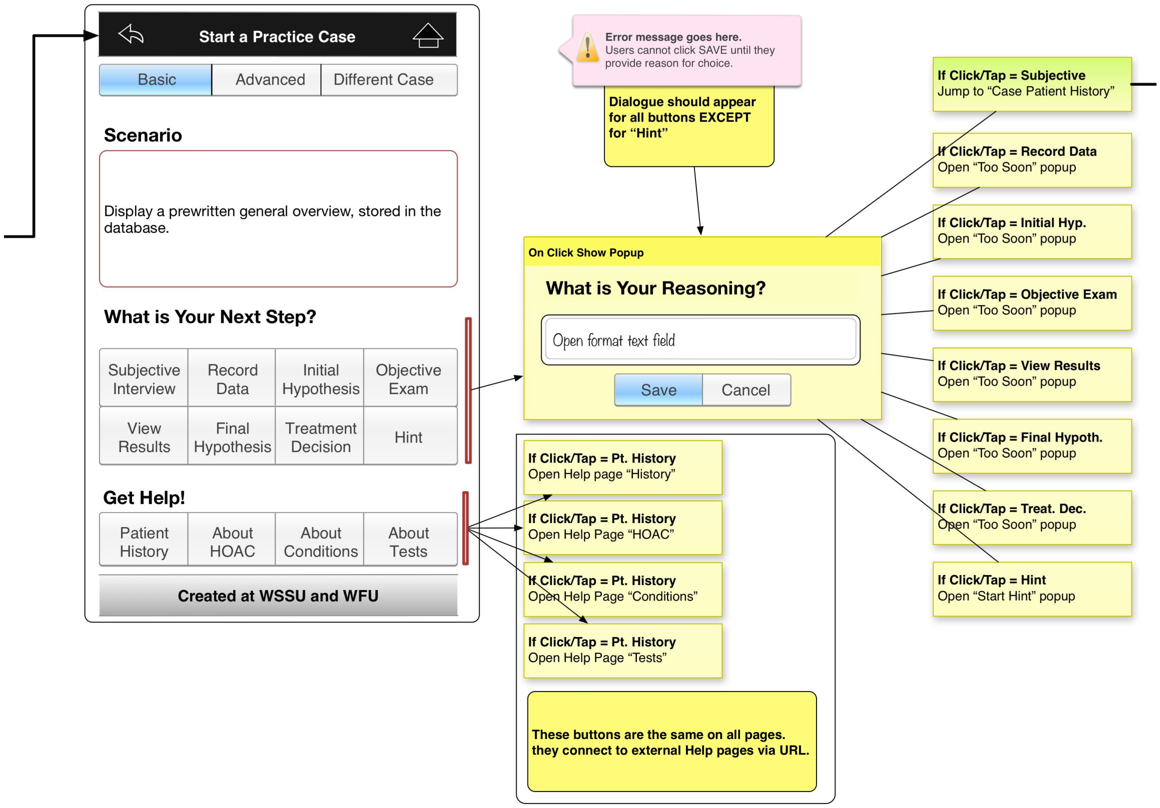
From this design process, the application wireframes were completed as depicted in Figure 3.13, below, using descriptive panels to provide guidance for programming the mobile application.

Figure 3.13. Application Wireframe Design.

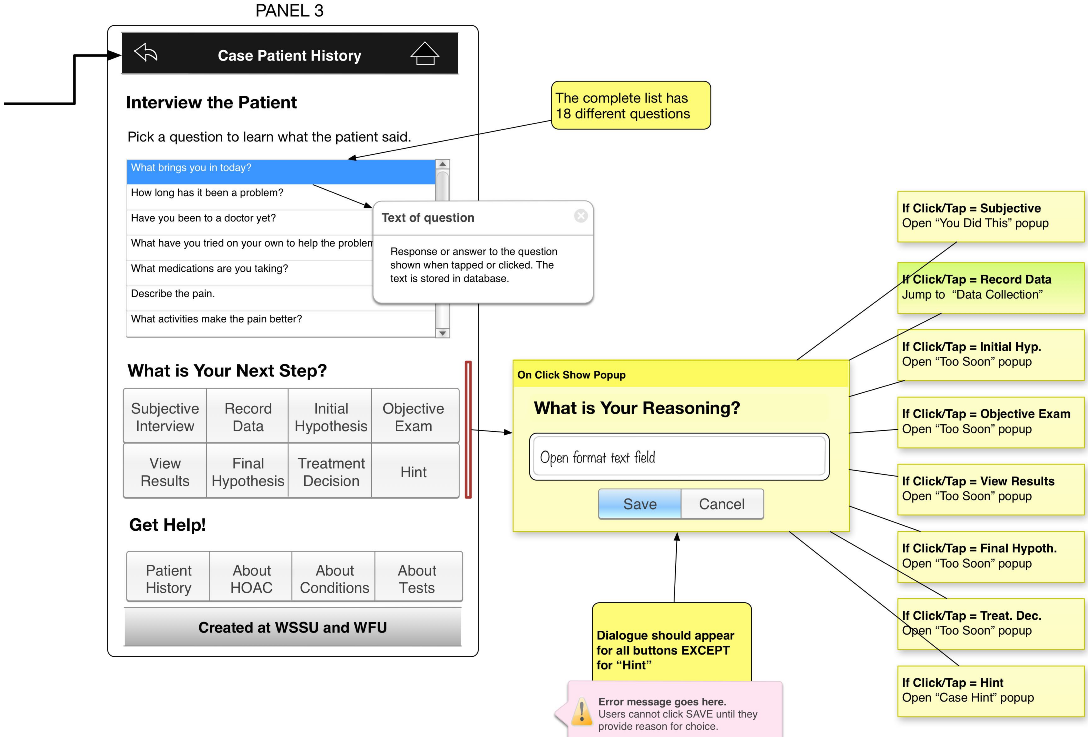


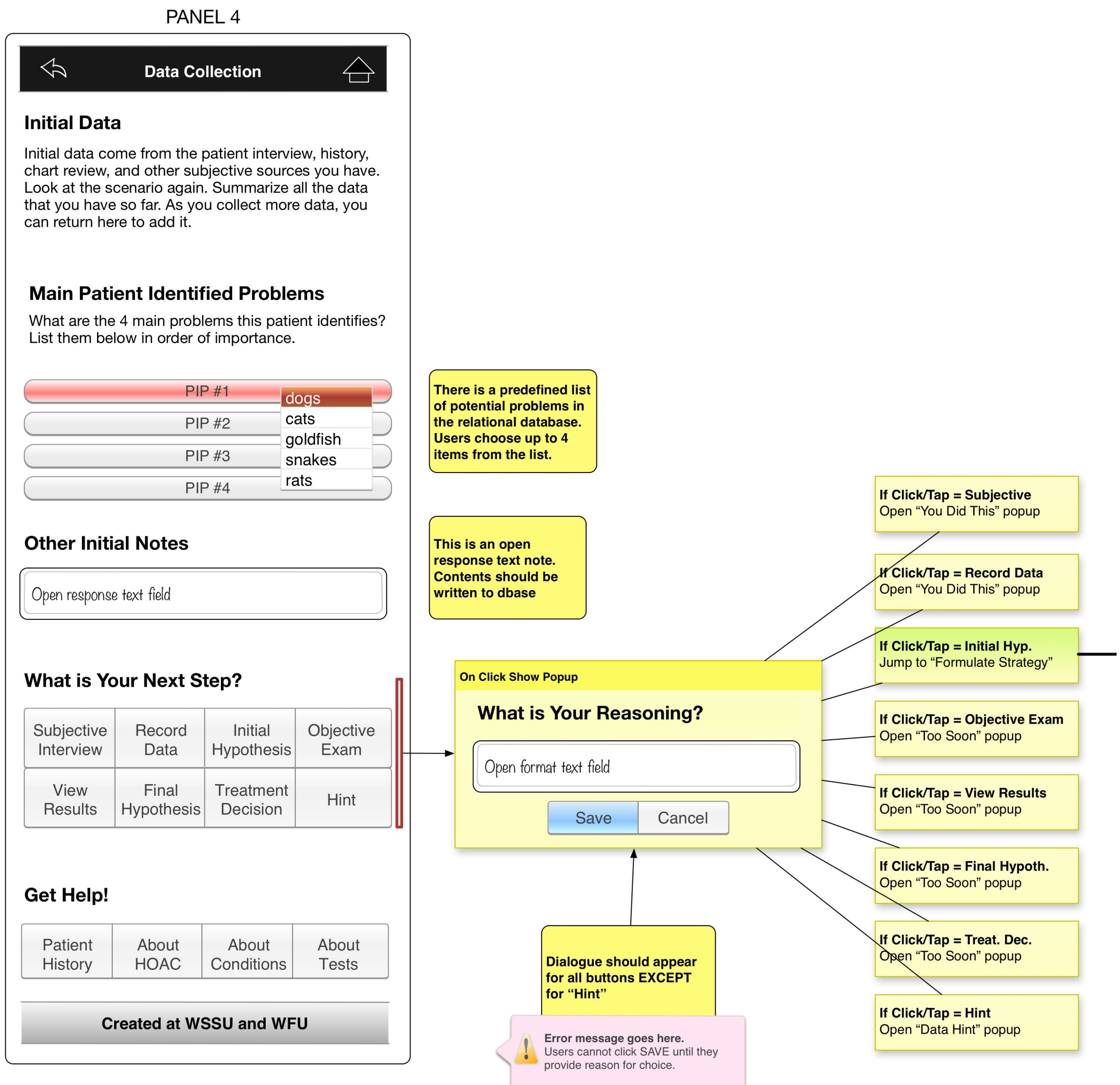
PANEL 1
Home
About HOAC Trainer App
Display a prewritten general overview.
Get Started:
User Log-In
Start a Practice Case Scenario
Start a New Patient
Tutorial
About the Trainer / Feedback
Created at WSSU and WFU
On Click/Tap
Open Login dialogue
On Click/Tap
Jump to “Start a Practice Case”
On Click/Tap
Jump to #10 “Live Patient History”
On Click/Tap
Jump to “Tutorial” (external HTML page)
On Click/Tap
Jump to “Feedback”

PANEL 2

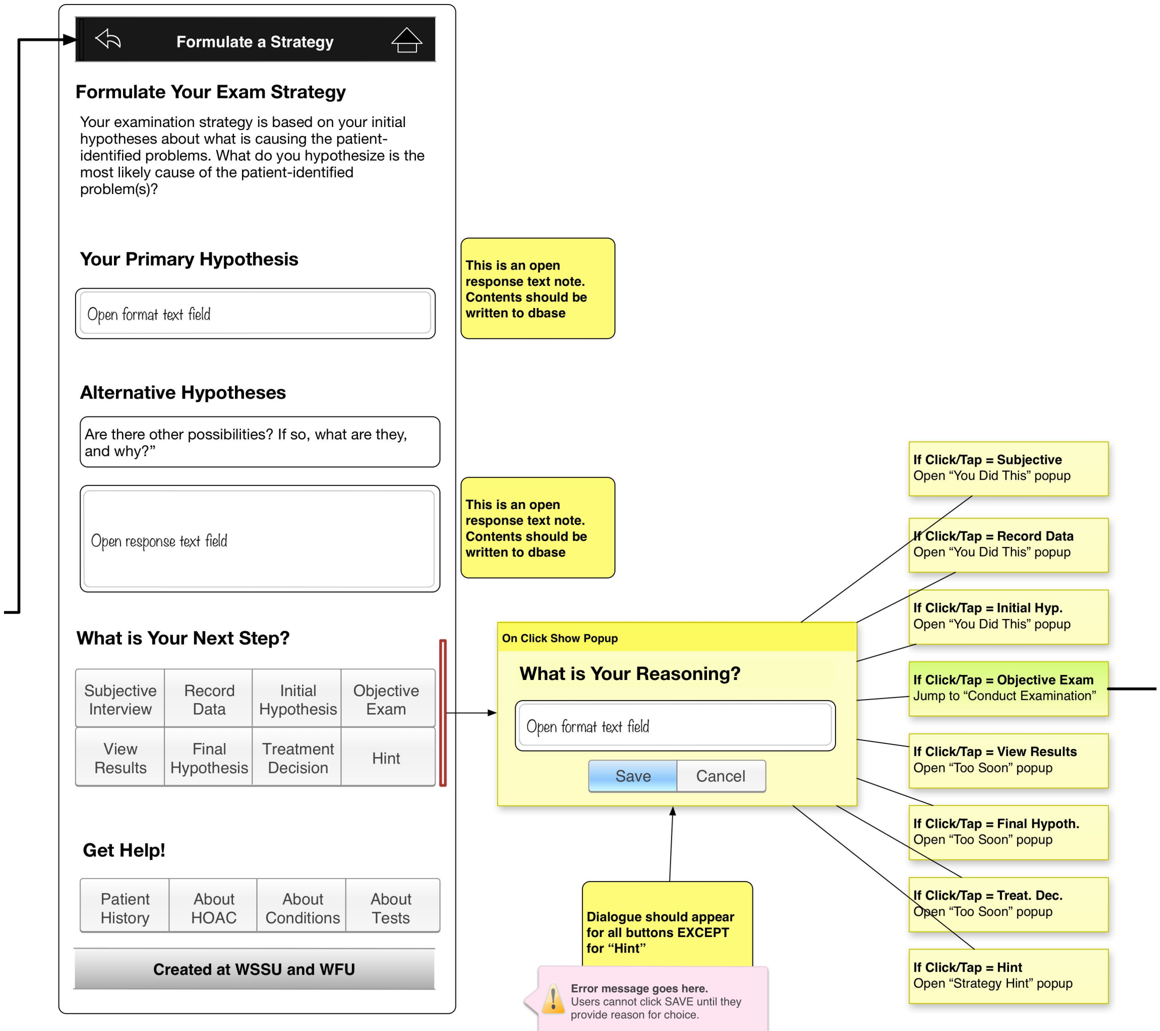


PANEL 3

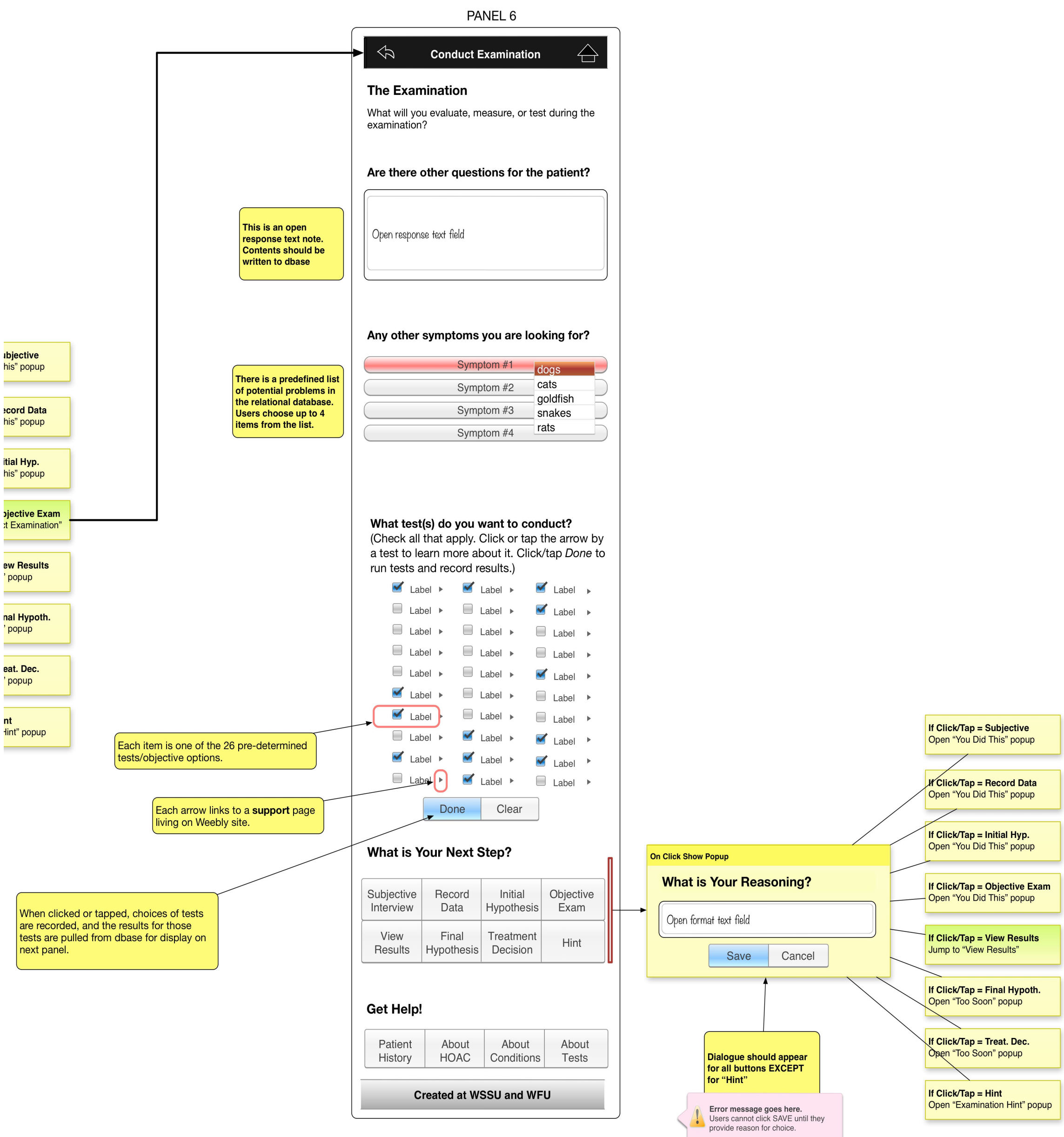


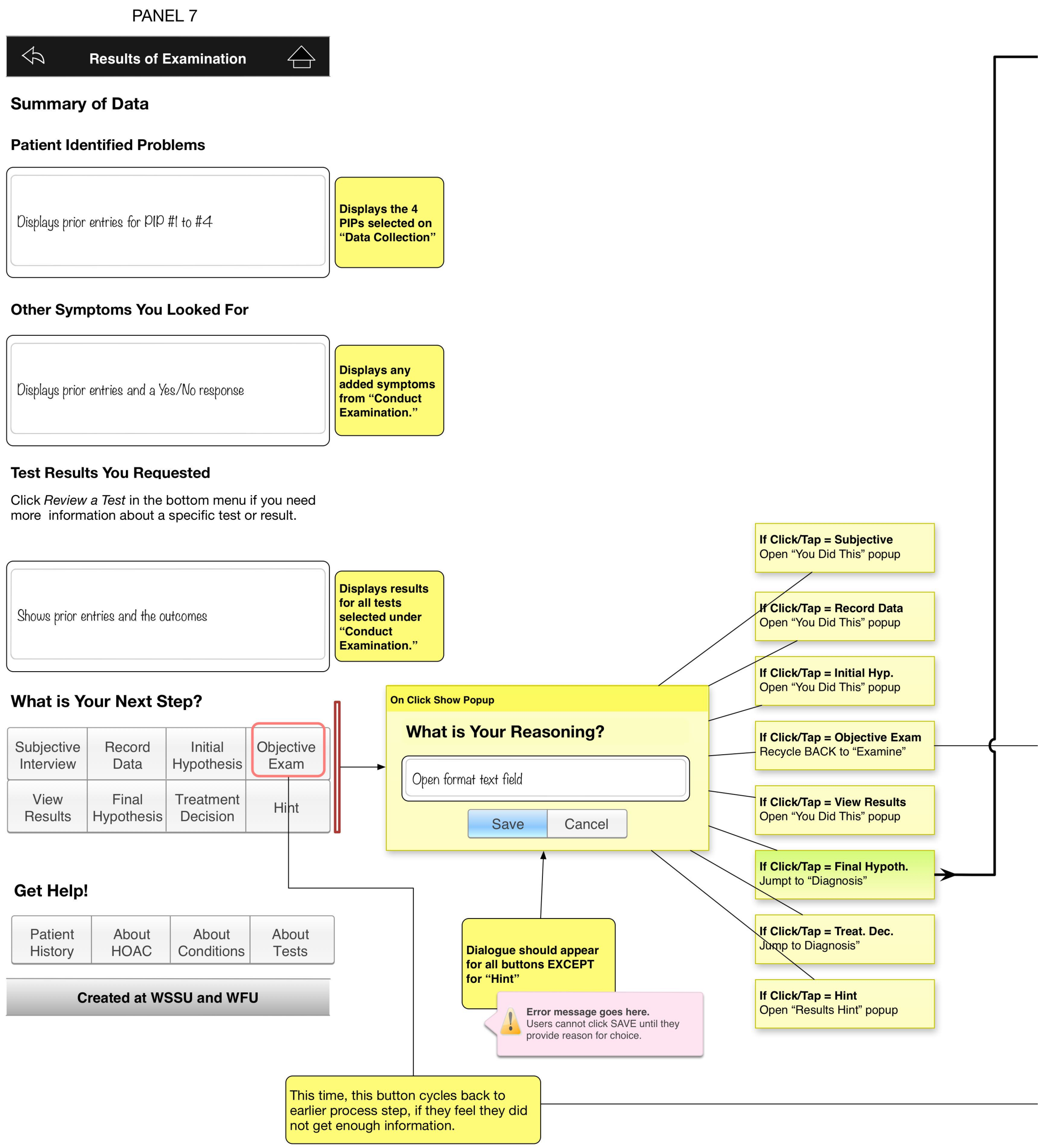

PANEL 4
Data Collection
Initial Data
Initial data come from the patient interview, history, chart review, and other subjective sources you have. Look at the scenario again. Summarize all the data that you have so far. As you collect more data, you can return here to add it.
Main Patient Identified Problems
What are the 4 main problems this patient identifies? List them below in order of importance.
PIP #1
PIP #2
PIP #3
PIP #4
dogs
cats
goldfish
snakes
rats
Other Initial Notes
Open response text field
What is Your Next Step?
Subjective Interview
Record Data
Initial Hypothesis
Objective Exam
View Results
Final Hypothesis
Treatment Decision
Hint
Get Help!
Patient History
About HOAC
About Conditions
About Tests
Created at WSSU and WFU
There is a predefined list of potential problems in the relational database. Users choose up to 4 items from the list.
This is an open response text note. Contents should be written to dbase
On Click Show Popup
What is Your Reasoning?
Open format text field
Save
Cancel
Dialogue should appear for all buttons EXCEPT for "Hint"
Error message goes here.
Users cannot click SAVE until they provide reason for choice.
If Click/Tap = Subjective
Open "You Did This" popup
If Click/Tap = Record Data
Open "You Did This" popup
If Click/Tap = Initial Hyp.
Jump to "Formulate Strategy"
If Click/Tap = Objective Exam
Open "Too Soon" popup
If Click/Tap = View Results
Open "Too Soon" popup
If Click/Tap = Final Hypoth.
Open "Too Soon" popup
If Click/Tap = Treat. Dec.
Open "Too Soon" popup
If Click/Tap = Hint
Open "Data Hint" popup

PANEL 5

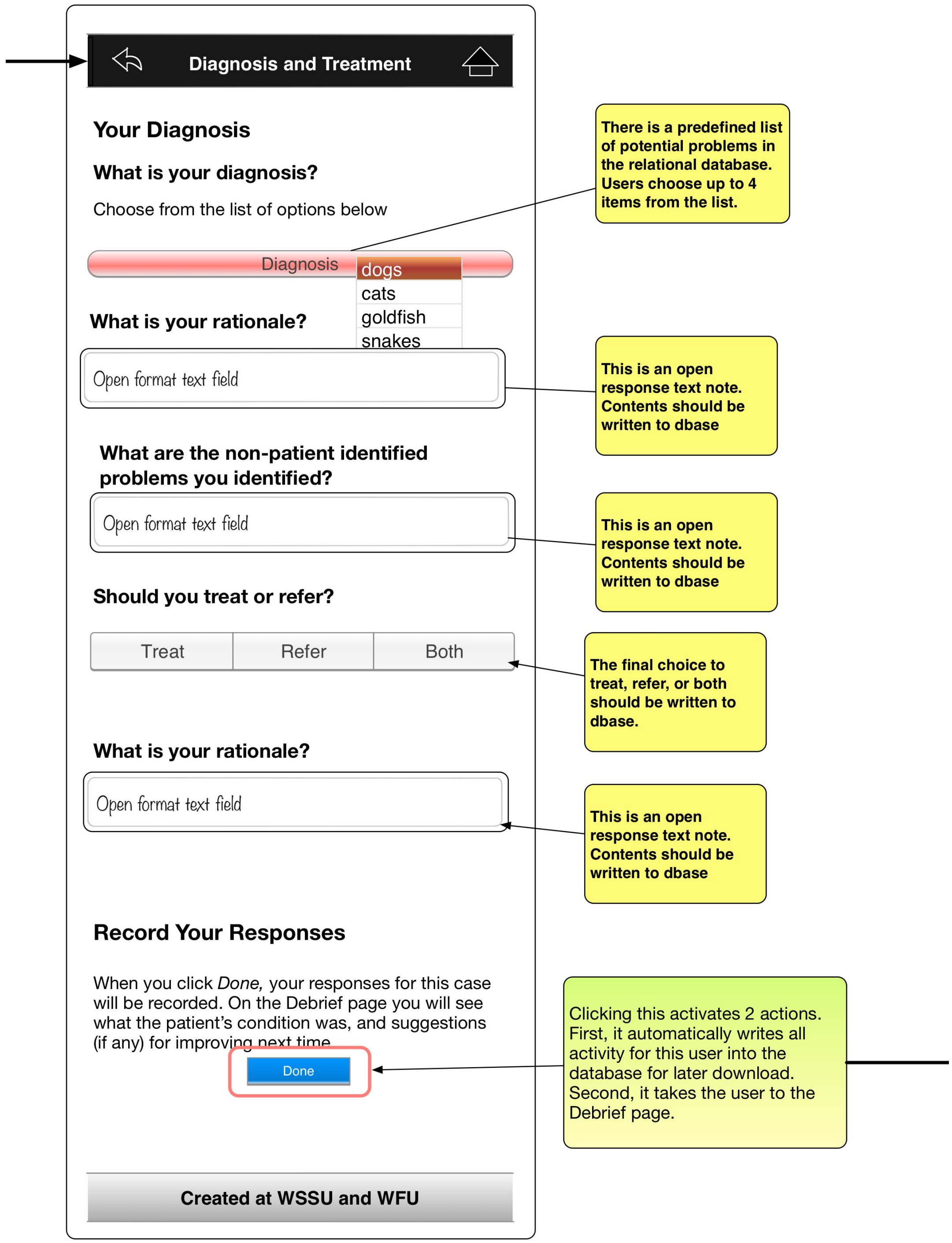


Formulate a Strategy
Formulate Your Exam Strategy
Your examination strategy is based on your initial hypotheses about what is causing the patient-identified problems. What do you hypothesize is the most likely cause of the patient-identified problem(s)?
Your Primary Hypothesis
Open format text field
This is an open response text note. Contents should be written to dbase
Alternative Hypotheses
Are there other possibilities? If so, what are they, and why?"
Open response text field
This is an open response text note. Contents should be written to dbase
What is Your Next Step?
Subjective Interview
Record Data
Initial Hypothesis
Objective Exam
View Results
Final Hypothesis
Treatment Decision
Hint
Get Help!
Patient History
About HOAC
About Conditions
About Tests
Created at WSSU and WFU
On Click Show Popup
What is Your Reasoning?
Open format text field
Save
Cancel
Dialogue should appear for all buttons EXCEPT for "Hint"
Error message goes here.
Users cannot click SAVE until they provide reason for choice.
If Click/Tap = Subjective
Open "You Did This" popup
If Click/Tap = Record Data
Open "You Did This" popup
If Click/Tap = Initial Hyp.
Open "You Did This" popup
If Click/Tap = Objective Exam
Jump to "Conduct Examination"
If Click/Tap = View Results
Open "Too Soon" popup
If Click/Tap = Final Hypoth.
Open "Too Soon" popup
If Click/Tap = Treat. Dec.
Open "Too Soon" popup
If Click/Tap = Hint
Open "Strategy Hint" popup


PANEL 6
Conduct Examination
The Examination
What will you evaluate, measure, or test during the examination?
Are there other questions for the patient?
Open response text field
This is an open response text note. Contents should be written to dbase
Any other symptoms you are looking for?
There is a predefined list of potential problems in the relational database. Users choose up to 4 items from the list.
Symptom #1
Symptom #2
Symptom #3
Symptom #4
dogs
cats
goldfish
snakes
rats
What test(s) do you want to conduct? (Check all that apply. Click or tap the arrow by a test to learn more about it. Click/tap Done to run tests and record results.)
Label
Each item is one of the 26 pre-determined tests/objective options.
Each arrow links to a support page living on Weebly site.
Done
Clear
When clicked or tapped, choices of tests are recorded, and the results for those tests are pulled from dbase for display on next panel.
What is Your Next Step?
Subjective Interview
Record Data
Initial Hypothesis
Objective Exam
View Results
Final Hypothesis
Treatment Decision
Hint
Get Help!
Patient History
About HOAC
About Conditions
About Tests
Created at WSSU and WFU
On Click Show Popup
What is Your Reasoning?
Open format text field
Save
Cancel
Dialogue should appear for all buttons EXCEPT for "Hint"
Error message goes here.
Users cannot click SAVE until they provide reason for choice.
If Click/Tap = Subjective
Open "You Did This" popup
If Click/Tap = Record Data
Open "You Did This" popup
If Click/Tap = Initial Hyp.
Open "You Did This" popup
If Click/Tap = Objective Exam
Open "You Did This" popup
If Click/Tap = View Results
Jump to "View Results"
If Click/Tap = Final Hypoth.
Open "Too Soon" popup
If Click/Tap = Treat. Dec.
Open "Too Soon" popup
If Click/Tap = Hint
Open "Examination Hint" popup


PANEL 7
Results of Examination
Summary of Data
Patient Identified Problems
Displays prior entries for PIP #1 to #4
Displays the 4 PIPs selected on "Data Collection"
Other Symptoms You Looked For
Displays prior entries and a Yes/No response
Displays any added symptoms from "Conduct Examination."
Test Results You Requested
Click Review a Test in the bottom menu if you need more information about a specific test or result.
Shows prior entries and the outcomes
Displays results for all tests selected under "Conduct Examination."
What is Your Next Step?
Subjective Interview
Record Data
Initial Hypothesis
Objective Exam
View Results
Final Hypothesis
Treatment Decision
Hint
Get Help!
Patient History
About HOAC
About Conditions
About Tests
Created at WSSU and WFU
On Click Show Popup
What is Your Reasoning?
Open format text field
Save
Cancel
Dialogue should appear for all buttons EXCEPT for "Hint"
Error message goes here.
Users cannot click SAVE until they provide reason for choice.
This time, this button cycles back to earlier process step, if they feel they did not get enough information.
If Click/Tap = Subjective
Open "You Did This" popup
If Click/Tap = Record Data
Open "You Did This" popup
If Click/Tap = Initial Hyp.
Open "You Did This" popup
If Click/Tap = Objective Exam
Recycle BACK to "Examine"
If Click/Tap = View Results
Open "You Did This" popup
If Click/Tap = Final Hypoth.
Jumpt to "Diagnosis"
If Click/Tap = Treat. Dec.
Jump to Diagnosis"
If Click/Tap = Hint
Open "Results Hint" popup

PANEL 8



Diagnosis and Treatment
Your Diagnosis
What is your diagnosis?
Choose from the list of options below
Diagnosis
dogs
cats
goldfish
snakes
What is your rationale?
Open format text field
What are the non-patient identified problems you identified?
Open format text field
Should you treat or refer?
Treat
Refer
Both
What is your rationale?
Open format text field
Record Your Responses
When you click *Done,* your responses for this case will be recorded. On the Debrief page you will see what the patient's condition was, and suggestions (if any) for improving next time.
Done
Created at WSSU and WFU
There is a predefined list of potential problems in the relational database. Users choose up to 4 items from the list.
This is an open response text note. Contents should be written to dbase
This is an open response text note. Contents should be written to dbase
The final choice to treat, refer, or both should be written to dbase.
This is an open response text note. Contents should be written to dbase
Clicking this activates 2 actions. First, it automatically writes all activity for this user into the database for later download. Second, it takes the user to the Debrief page.

Referenced within the wireframes is the need for a database to store information. Therefore, after the wireframes were developed, an Excel database was created to form the basis for a jQuery mobile database to underpin the application. The use of a database for this project was framed by two goals. One goal was to structure the database so that it contained a limited condition set of objective tests, results, and subjective responses related to the diagnosis of lower-extremity vascular disorders to limit access to data choices during sense making. The second goal of the database was to structure the linkages between the objective tests, results, and subjective responses and to return them to the user to manage non-salient tasks during the reasoning process. In addition to the database being created, nine clinical cases were developed and reviewed by two experts in the PT profession. From the review, cases were modified to best represent expert opinion and the practice of physical therapy, and were subsequently integrated into the mobile application within the case-based portion of the mobile application.

Development of the Mobile Application

The next section of this chapter describes the steps taken in the next step of the ADDIE framework, development. Further described within this section are modifications made to the mobile application as the application was tested during development.

Following creation of the cases, the Excel file, and wireframes, a request for quotes was sent to several application developers, and an application developer was selected. From this initial development process, a mobile application was developed based upon the wireframes, expert-reviewed cases, and the database.

After the initial development process, the application was alpha tested. Alpha testing revealed an issue with how the application managed data for non-salient tasks. The application was modified to provide summative data to the user at more points in the process in order to help with data collection and management. This modification is depicted in Table 3.3, and depicted in Figure 3.14, from the finalized application.

Table 3.3. Additional Features of the Mobile Application Elements and the Scaffolding Design Framework Model (Quintana, 2004).

Application Feature	Scientific Inquiry Component	Guideline	Scaffolding Strategy	Type of scaffold (Sharma & Hannafin, 2007)
Data management for cognitive load/management of memory tasks, with data collected and returned at decisional points. Data were returned after the subjective exam to assist the learner in initial problem identification, after collecting objective data to assist the learner in generating the non-patient identified problem list, and on the final hypothesis generation, and on debriefing screen to support reflection.	Process management	Guideline 6: Automatically handle non-salient, routine tasks.	6b. Facilitate the organization of work products	Hard

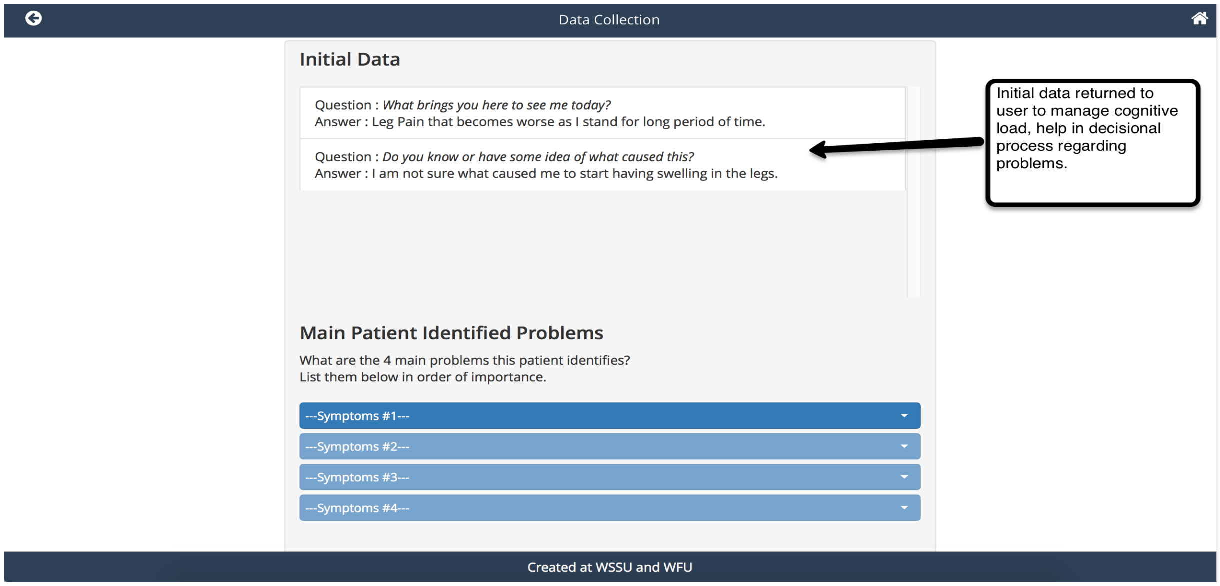


Figure 3.14. Information Returned at Decisional Points.

Following the completion of these modifications to the mobile application, another round of alpha testing was conducted. During this round of alpha testing, errors were corrected, and two issues were identified. One issue was related to making the application more flexible so that conditions or cases could be added after the testing period was over. This resulted in the addition of an administrative panel that allowed modifications of the application by adding or deleting cases or expert recommendations for tests. Exemplars from this panel are depicted in figures 3.15 and 3.16. Further modification to the mobile application occurred to allow administrators to be added, questions on the subjective screen to be added or deleted, objective tests to be added or deleted, help resources to be added or deleted, and diagnoses to be added or deleted. Two exemplars from this panel are depicted in figure 3.17.

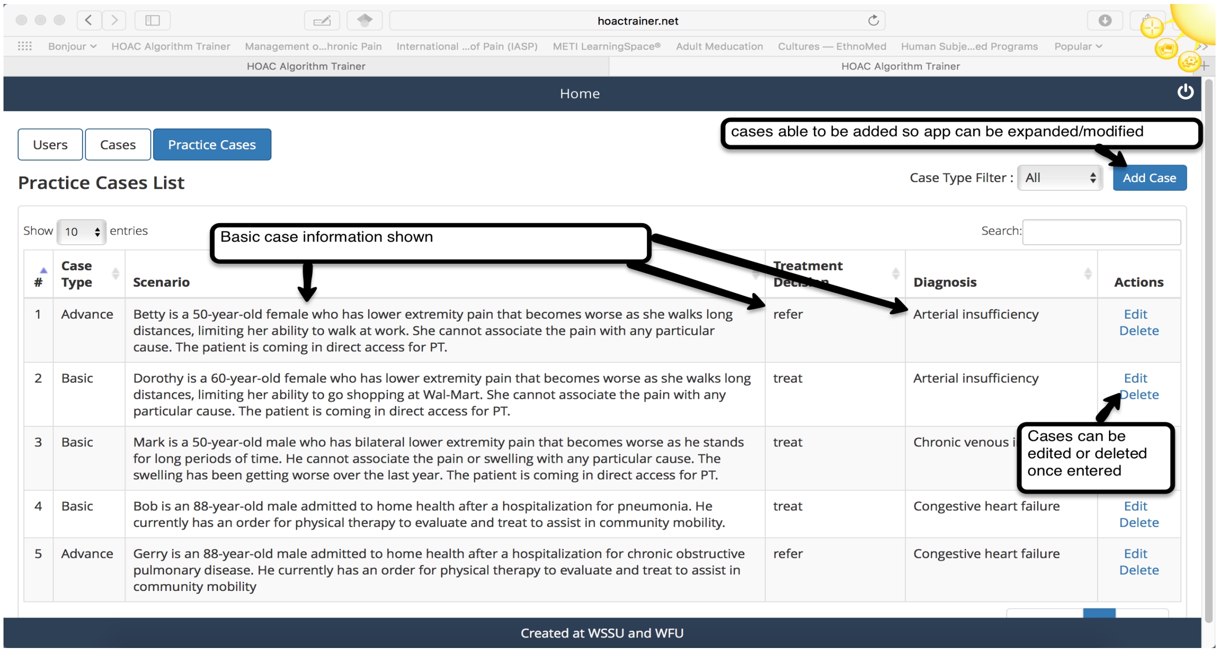


Figure 3.15. Practice Case Modification Panel.

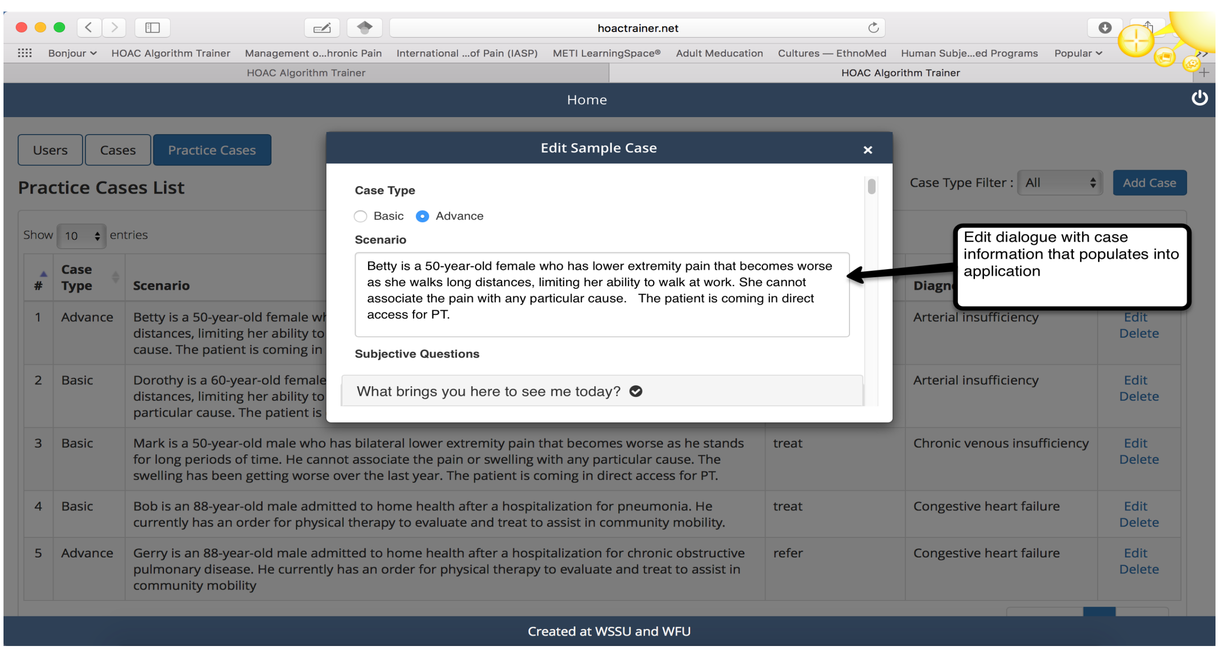
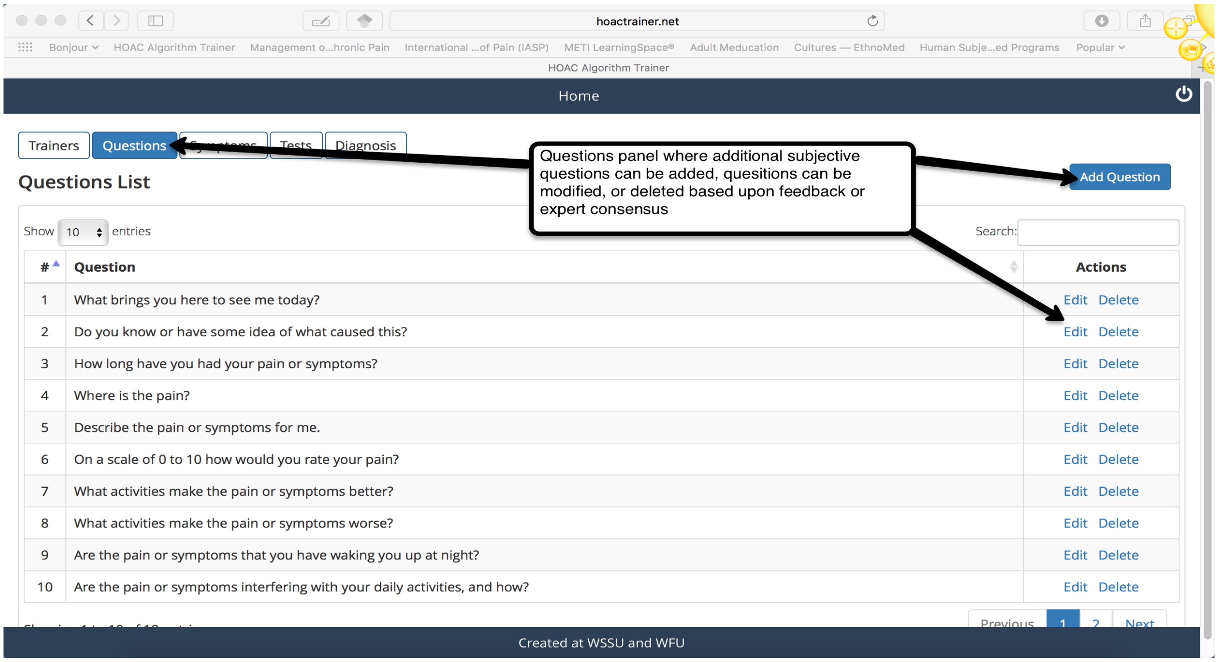


Figure 3.16. Practice Case Edit Dialogue.



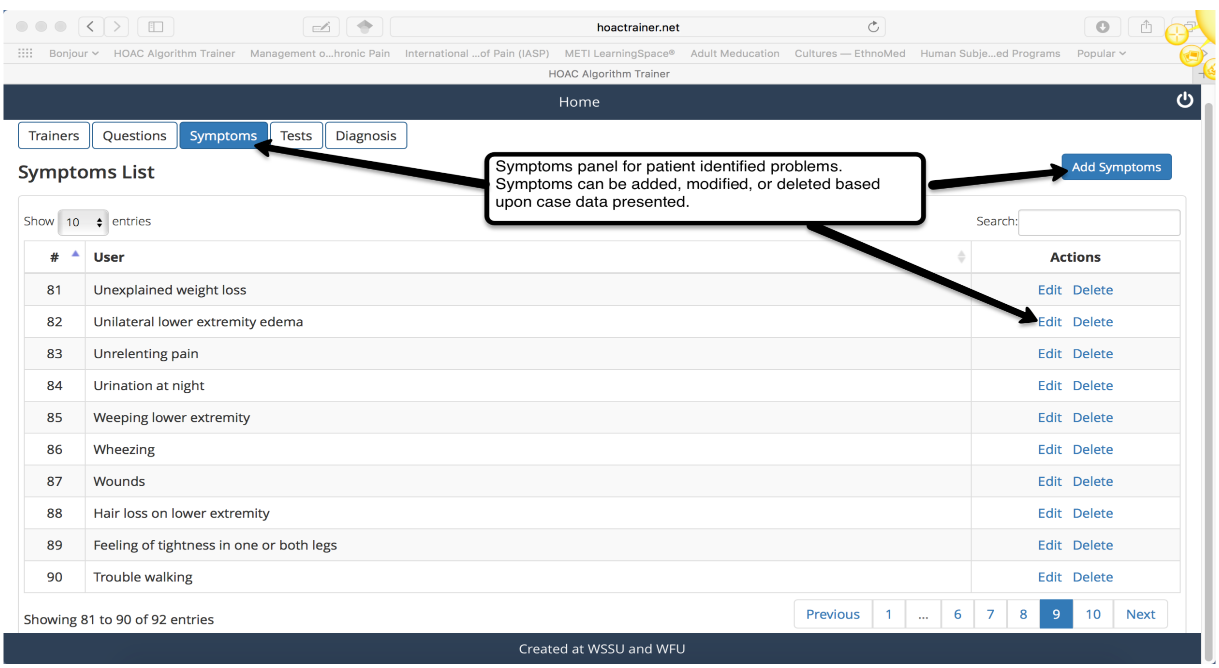


Figure 3.17. Database Modification Panel Exemplars for Addition of Questions, Symptoms, Tests, or Diagnoses.

The second issue identified during alpha testing related to being able to collect background analytics to quantify time on-screen and steps taken by the user. This functionality was added to a second administrative panel so that user inputs into the mobile application could be collected for later analysis. This panel is depicted in Figure 3.18, below, and the outputs derived from this panel, related to time stamp data and user inputs are depicted in Figure 3.19 and Figure 3.20, respectively.

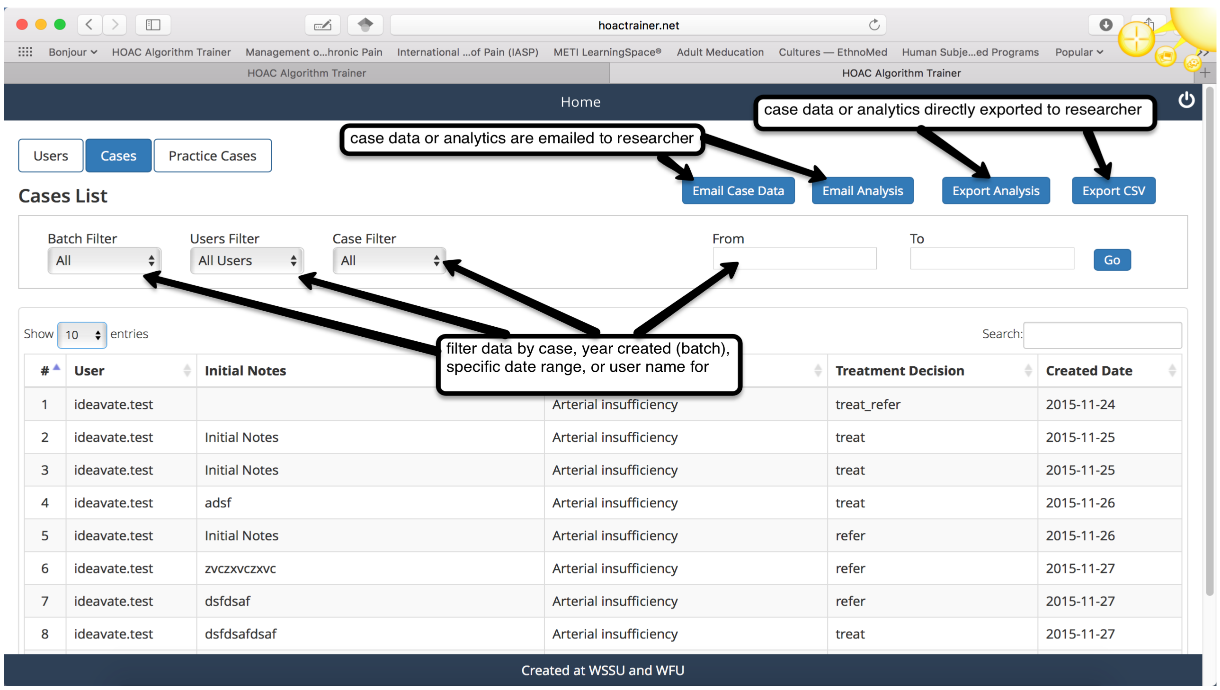


Figure 3.18. Case Data Export Panel.

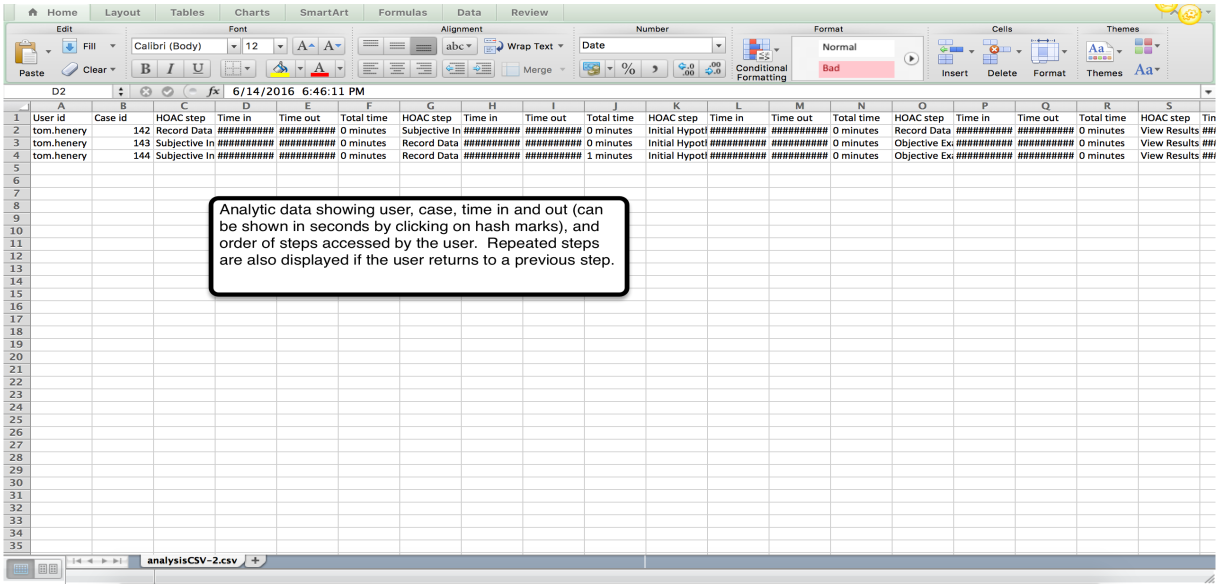


Figure 3.19. Database Exemplar: Time Stamp Data Exemplifying Time by HOAC-II-1 Step.

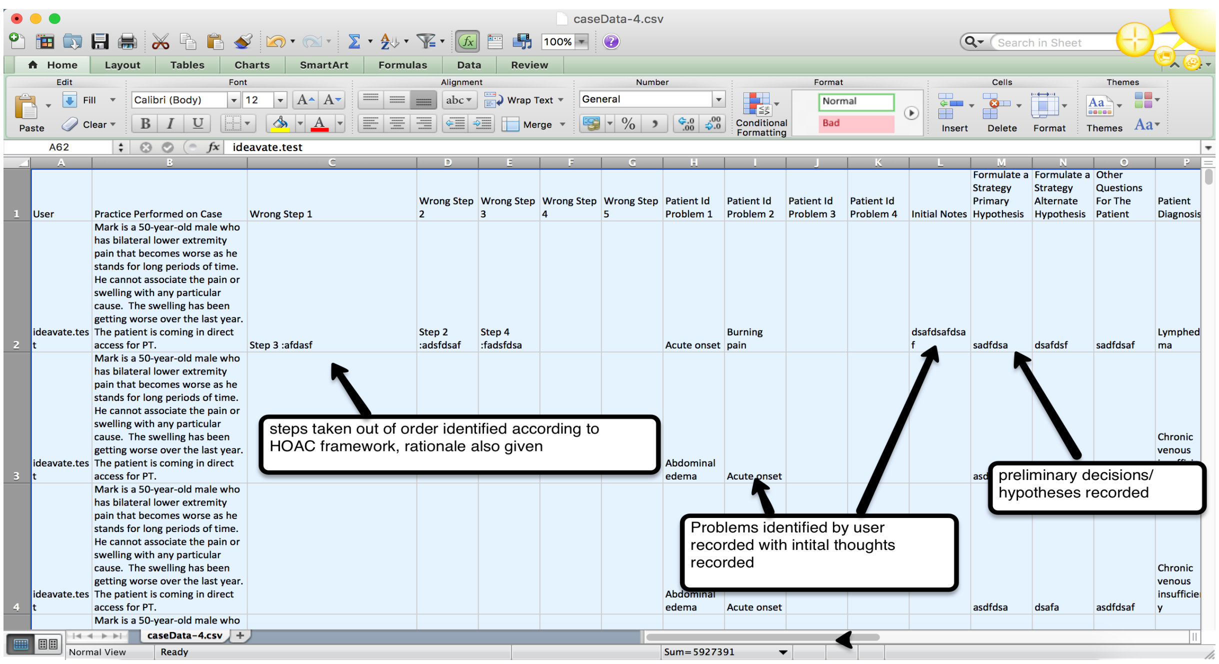


Figure 3.20. Database Exemplar: User Data Exemplifying Order of Steps in the Process and User Entries into Mobile Application.

After these panels were added, further testing was conducted to detect any errors in the program, and the application was finalized for study.

Conclusion

This chapter has described the first three steps in the ADDIE design framework, analysis, design, and development as it pertains to the mobile application under study, in order to describe scaffolding features incorporated that may facilitate higher order clinical reasoning strategies, improve the sequence of clinical reasoning, and allow the researcher to understand what scaffolds PT student-participants learning clinical reasoning most rely upon. The next chapter, Chapter 4, will describe the next steps of the ADDIE framework, implementation and evaluation, to provide a methodology for discovering if the design processes implemented achieve the stated goals for the application related to facilitation of scientific clinical reasoning sequence and strategies and understanding the support of scaffolding for the scientific clinical reasoning process.

CHAPTER FOUR: RESEARCH DESIGN AND METHODOLOGY

Previous research has not explored the use of mobile-based technology applications to provide scaffolding for ill-defined problems within the profession of physical therapy to facilitate physical therapist (PT) students' scientific (hypothetical deductive) clinical reasoning processes, and limited research exists on the use of mobile technology within the profession of education to scaffold scientific reasoning. Furthermore, no educational mobile application developed to date has employed the number and type of scaffolds employed within the mobile application evaluated in this study. This research study utilized a researcher-generated mobile application that was designed using mobile-based scaffolds to support the sequencing of the PT evaluative process in congruence with the Hypothesis Oriented Algorithm Framework II-Part 1 (HOAC II-1). The purpose of the study was to detect the influence, if any, that use of the application had upon the development of clinical reasoning strategies and sequence of PT student-participants' scientific clinical reasoning strategies. The following research questions were explored.

Overarching Research Question

The overarching question was as follows: How are PT student-participants' scientific clinical reasoning —specifically their evaluation and examination processes (related to hypothesis generation), their clinical decision-making (regarding treatment appropriateness), their use of clinical reasoning strategies, and their sequencing of scientific clinical reasoning — influenced by a mobile application that provides scaffolds to the HOAC II-1 clinical reasoning process?

Sub-questions Related to the Problem

Two sub-questions were explored in order to elucidate facets of the overarching research question.

Research question 1. How are PT student-participants' clinical reasoning strategies and sequence of scientific clinical reasoning and hypothesis generation influenced by a mobile application's scaffolding of the HOAC II-1 framework?

Research Question 2. What soft scaffolds within the mobile application do PT student-participants rely upon most often to inform their scientific clinical reasoning process, and how does that reliance change over three different practice sessions?

Overall Research Design

In order to evaluate the utility of the mobile application in facilitating student learning of scientific clinical reasoning strategies using the implementation and evaluation phases of the ADDIE model, an intervention-based, sequential, qualitative research design (QUAL→ QUAL→ QUAL) was used (Creswell & Clark, 2010; Creswell, 2015). A full illustration of the research design is presented in Figure 4.1 below (Creswell, 2015).

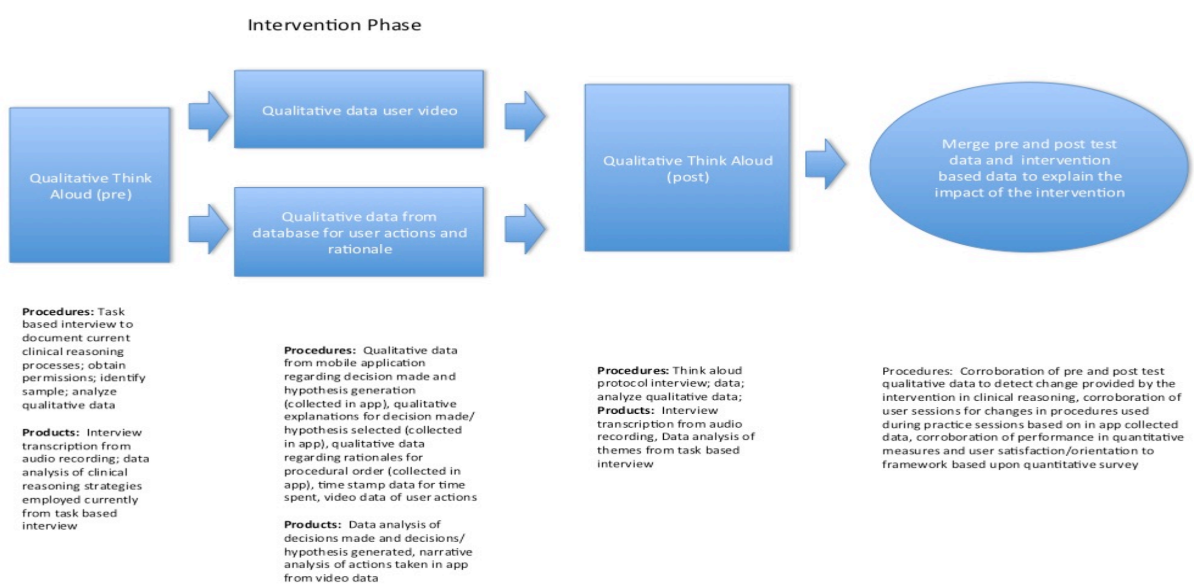


Figure 4.1. Research Design of the Study Including Procedures and Products.

An illustration of the links between the research questions and the data sources collected in the methods described subsequently is provided in Table 4.1, below.

Table 4.1. Research Questions and Data Sources Utilized to Answer the Research Question.

Research Question	Data Sources
The overarching question was as follows: How are PT student-participants' cognitive clinical reasoning—specifically their evaluation and examination processes (related to hypothesis generation), their clinical decision-making (regarding treatment appropriateness), their use of clinical reasoning strategies, and their sequencing of clinical reasoning—influenced by a mobile application that provides scaffolds to the HOAC II-1 clinical reasoning process?	Pre/post task-based interview data Researcher field notes Participant form Video data of application interaction Application analytic data Qualitative user inputs to mobile application
RQ 1: How are PT student-participants' strategies and sequence of clinical reasoning and hypothesis generation influenced by a mobile application's scaffolding of the HOAC II-1 framework?	Pre/post task-based interview data Post only interview data Researcher field notes Participant form
RQ 2: What soft scaffolds within the mobile application do physical therapy student-participants rely upon most often to inform the clinical reasoning process, and how does that reliance change over three different practice sessions?	Video data of application interaction Application analytic data Qualitative user inputs to mobile application

Data Collection Methods

Described subsequently within this section are the methods utilized to collect data. First student participant recruitment is described. Secondly, the phases of the study are described. Finally, data collected during the study is outlined and a justification of the data collection methodology is provided.

Student-Participants and Participant Recruitment

The student-participants recruited for this study were first-year PT students from a medium-sized, four-year public, Level V Carnegie-classed (Schnur, 2007) institution located in the southeastern United States, with a doctoral PT program. The PT program at this institution has approximately 28 students per cohort, with three cohorts enrolled at one time. Cohorts are divided by gender equally, with 50% male and 50% female students. Thirty percent of the student population enrolled in the program had self-identified upon program entry as belonging to a minority group.

Six student-participants were selected to participate using purposeful sampling (Portney & Watkins, 2008). To purposefully select the sample, potential student-participants were first asked to complete a demographic survey that asked, via an email recruitment script (Appendix A), for the following information: year in the physical therapy program, racial/ethnic identity, and gender. From those individuals (N=12, 42.8% response rate) that completed the consent form for the collection of demographic data (Appendix B) and the demographic survey, a purposeful sample was selected by the researcher that represented the currently enrolled student body by gender and minority status. Subsequently, emails were sent to the purposefully selected prospective student-participants to solicit participation in the full study (Appendix C).

The rationale for using purposeful sampling was twofold. First, this method allowed the sample to be representative of the currently enrolled student population with respect to gender (50% male, 50% female) and minority status (30%). Secondly, this method enabled the selection of first-year students for participation, which is important because previous studies have demonstrated that beginning students have relative inexperience with clinical reasoning in physical therapy and tend to employ unsophisticated reasoning strategies (Gilliland, 2014).

Participant Demographics

Student-participants, who have been given pseudonyms, selected for study, constitute a representative sample of their cohort, being composed of 33% male and 66% female (cohort:

30% male, 70% female), 50% majority and 50% minority (cohort: 60% majority, 40% minority), and with an average age of 24.33 (cohort average age 23). Participant demographics are noted in Table 4.2 below.

Table 4.2. Participant Demographics.

Participant	Age	Race	Undergraduate Major	Clinical Reasoning Experience	Gender
Sara	25	white	Exercise Science/Athletic Training	Yes, in Athletic Training	female
Bryan	23	white	Exercise Science	No	male
Marcus	23	black	Exercise Physiology	No	male
Shannon	22	black	Physical Education	No	female
Kerry	23	black	Exercise Science	No	female
Charlotte	27	white	Psychology	No	female

Pre-Intervention Phase

After these student-participants had agreed to participate in the full study and completed informed consent documents (Appendix D), each participant completed a *semi-structured task-based interview* (Appendix E) that was audio recorded. The purpose of the interview was to elicit hypothesis generation and clinical reasoning strategies that students used prior to interacting with the mobile application, as well as elicit attitudes about influential factors for clinical reasoning. At the start of this interview, student-participants were instructed in the expectations and process of the interview. Next, student-participants were given a sheet of paper (*participant form*—Appendix F) with an introduction to the clinical case used during the task-based interview process, on which they were asked to write any thoughts that they had regarding the case or any information that they needed to help them in the reasoning process. This form was collected at the end of the interview. During the interviews, the researcher provided information for sense making, procedural support for process management, or assistance with articulation and reflection to the student-participants in an effort to assist them in gaining data necessary to solve the patient problem, as student-participants solicited information about the case by questioning the interviewer (Appendix E). As data were provided to the student-participants, the researcher asked student-participants to describe the rationale for both the clinical reasoning strategies they used and the hypotheses generated towards diagnosis and appropriate treatment (Appendix E). Further questions were addressed to participants that elicited attitudes towards influential factors for clinical reasoning. Finally, further data were collected during task-based interviews using *researcher field notes* (Appendix G) in order to document researcher impressions of clinical reasoning strategies and the sequential order of examination and evaluation utilized during the task-based interview.

Intervention Phase

Subsequent to the *task-based interview* (Appendix E), student-participants had four one-hour intervention sessions with the mobile application, which took place over approximately six weeks. Each of these sessions were video recorded. Following the initial intervention session, consisting of instruction on the mobile application, student-participants participated in three different intervention sessions. During each intervention session, the participant utilized the application to practice their clinical reasoning using a single expert-reviewed case that focused on lower-extremity vascular disorders.

Mobile application use during the study period. During all sessions with the mobile application, after logging in with a unique, de-identified login, the participant selected a practice scenario case that received expert review, specific to lower-extremity vascular disorders. Users were allowed to select a case of their choosing from the case selection panel by tapping on the basic or advanced case tab (judged to be basic or advanced by the expert reviewers), scrolling through the introductory case descriptions provided on each tab, and reading the case description. However, student participants were not allowed to repeat a completed case during any intervention session in order to limit practice effects. This case selection process is depicted in Figure 4.2, below.

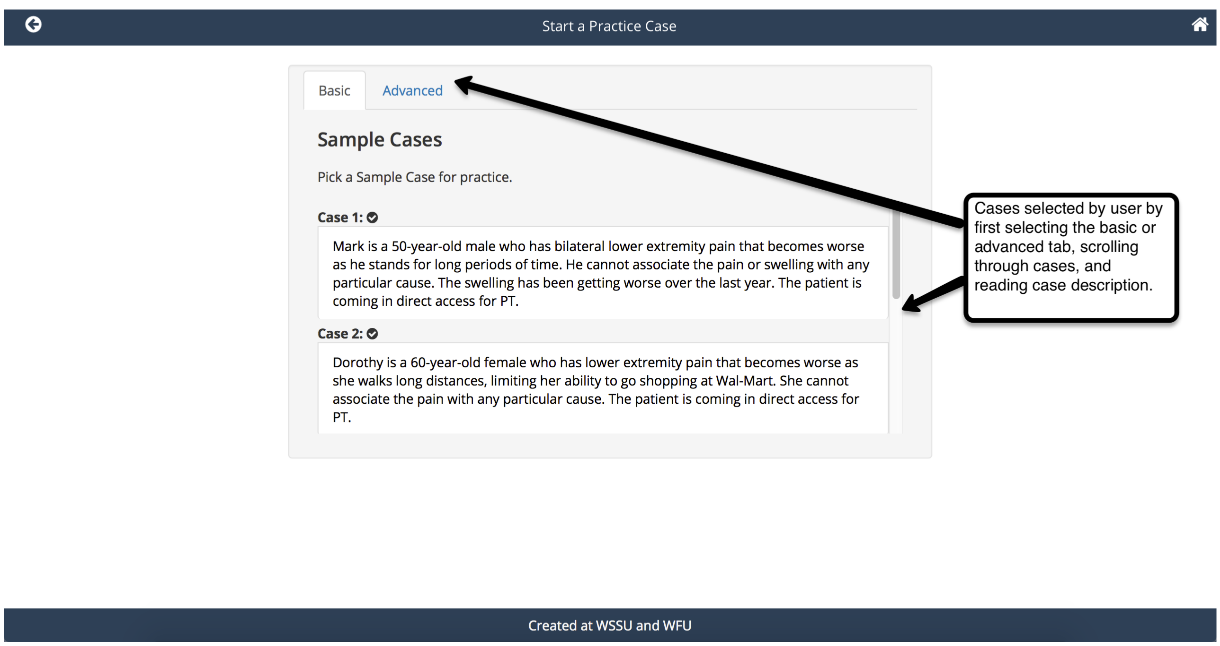


Figure 4.2. Case Selection Process.

Following case selection, in which all student-participants selected a basic case, a set of standardized buttons was presented with the case information. These buttons were consistently present on each subsequent screen except for the screens for diagnosis and treatment and for debriefing, consistent with process management scaffolding guidelines. Within the application, the buttons allowed the participant to either select a step in the HOAC II-1 or to seek help, in congruence with the sense making scaffolding guideline. Buttons were also utilized to provide help to student-participants to explain the steps in the patient history, the HOAC II-1 framework, the conditions represented within the cases, and the PT examination measures commonly utilized to attain a physical therapy diagnosis for the conditions covered in the cases. The participant was also able to obtain a hint about what step to pursue in the framework if they needed assistance. Further, if a participant selected an incorrect next step in the framework, the participant was asked for a rationale for the step selected to assist with reflection and articulation. The rationale entered was recorded into a database for later analysis.

Further screen layouts present within the mobile application allowed the collection of initial data, the identification of patient-identified problems, the generation of an initial hypothesis and alternate hypothesis, and the collection of examination data. Links were also provided to resources to provide knowledge support to guide sense making. Subsequent to collection of examination data, in congruence with the process management guideline, the database returned the initial patient-identified problems that had been identified, the test results, and other entries or notes that the participant entered, so that evaluation could occur. At this point, the participant could choose to either go back and collect more data by returning to the examination page, or else proceed to form a final diagnostic hypothesis and make a clinical decision whether to treat, refer, or treat and refer with a rationale for both (articulation and reflection scaffolding support). Participant data from these interactions were recorded to the database for later analysis, consisting of user entry into text boxes, time spent on each step, and the order in which steps were approached in the reasoning process. Following completion of the steps in the process, a debriefing screen was presented, scaffolding sense making as well as articulation and reflection. This screen presented the diagnoses and tests that the participant selected, and also provided information from an expert practitioner listing the actual diagnosis, the tests that should have been selected, the most appropriate treatment decision, and the rationale for the treatment or referral decision. Also displayed on the debriefing screen was an open-ended text box that allowed the user to enter a reflection on improvements needed for the next time. After entering their reflection on performance, the participant was able to choose to select another case, receive the case data by email, or save their data and exit. After an option was selected, the reflection data was recorded to the database for later analysis.

Within each of the intervention sessions, student-participants utilized case data and the structured scaffolds provided by the application to help shape their clinical reasoning and to help formulate clinical decisions related to the final diagnostic hypothesis reached and the decision to treat, refer, or both treat and refer the patient. While the application was in use, two forms of qualitative data were collected. First, *video data* were collected while the mobile application was in use; a video camera focused on the actions of the participant, and screencasting software recorded a screencast of the mobile application. Second, *mobile application analytic data* provided information about users' interactions with the application. Specifically, this included data on the *diagnostic hypothesis reached* and the *decision made to treat or not treat* the patient, as well as *rationales for decisions made*, *time spent* on each step in the HOAC II-1 framework, and the *order of the steps* pursued. Additionally, if a participant chose an out-of-order sequence, other qualitative data were collected on *rationales for order of steps taken in the diagnostic* *process*. Finally, qualitative data consisting of *user reflections on performance* were collected at the close of the case.

Following these four intervention sessions, a second *semi-structured task-based interview* (Appendix E) was conducted, following the same procedures as the initial task-based interview, with questions added that related to the mobile application's perceived utility and effects. Following data collection, data were analyzed using qualitative methods to determine the effects of the mobile application on the hypotheses generated, the clinical reasoning strategies employed, any changes in clinical reasoning processes, and the use of scaffolding. The analysis methods are described below.

Data Collected and Relationships to Research Questions

Research Question 1 was answered using multiple methods. The first method was an *audio-recorded task-based interview* process, conducted at two points: prior to student-participants' having experience with the mobile application under study (*pre-task-based interview*) and following (*post task-based interview*) all of the intervention sessions with the application. This method was utilized to elicit, pre- and post-intervention, the sequence of the reasoning process, the clinical reasoning strategy most utilized by the student-participants, attitudes towards factors that influence clinical reasoning, and changes in participant reasoning strategies over time, including scaffolds needed during the *task-based interview*s. Further corroboration occurred between the sequence and strategy utilized by the student participants to determine if using a particular sequence or a particular clinical reasoning strategy had any effect on the clinical reasoning outcome (diagnosis or treatment decision). Linkages between the conceptual framework utilized and the interview questions are provided in Table A.2 (Appendix J).

The second data source utilized to answer this research question was *researcher field notes* that were used to document researcher impressions of clinical reasoning strategies and the sequential order of examination and evaluation utilized during the task-based interview. Further corroboration of these data occurred through a triangulation process between user data obtained during practice sessions and the sequential processes expressed within the pre-and posttest interviews in order to elicit change over time.

The final data source utilized to answer this question was *qualitative user-entered data* from the application, which was collected during mobile application use. Three types of user data were collected: *inputs into the application when deviations from the HOAC II-1 algorithmic sequencing occurred*; *rationales for hypotheses generated or decisions made*; and *user reflections on needed changes in the evaluation and examination process* (collected on the debriefing page).

Research Question 2 was answered using *video data of user actions, screencasts of the application*, and *user analytic data*, all of which were collected during mobile application use. The observation protocol is located in Appendix I and is based upon Lee and Hollebrands (2006). While the application was in use, a singular camera was focused on the participant and the mobile device screen to capture user interactions with the mobile application. A screenshot, denoting these video data that were captured, are located below in Figure 4.3 and 4.4, below.

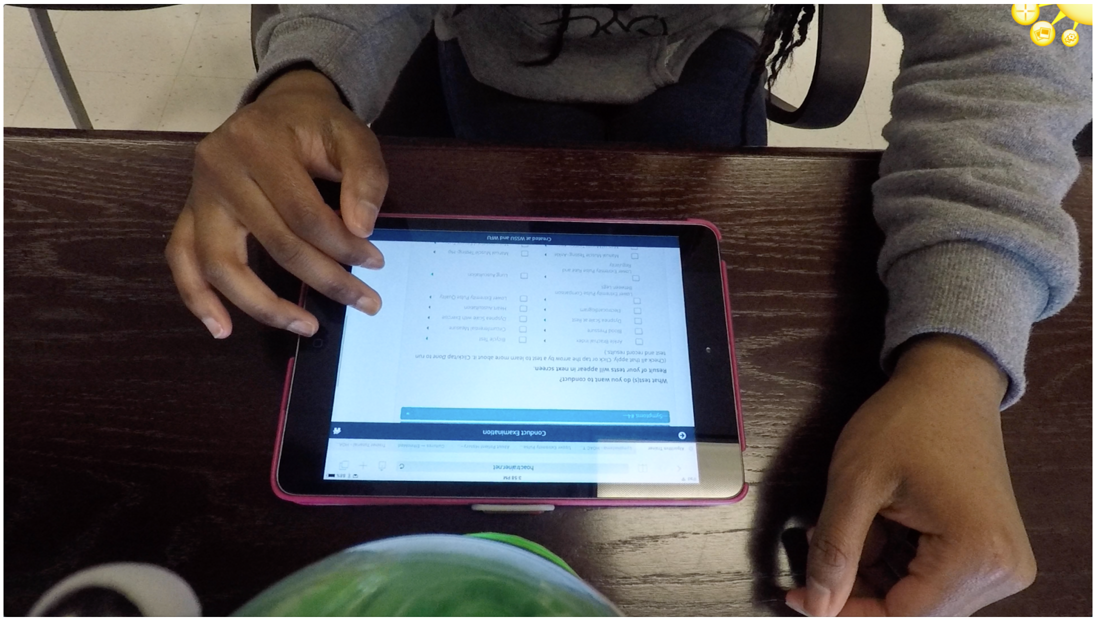


Figure 4.3. Depiction of Data Collection Procedure Used to Capture Student-Participant Actions.

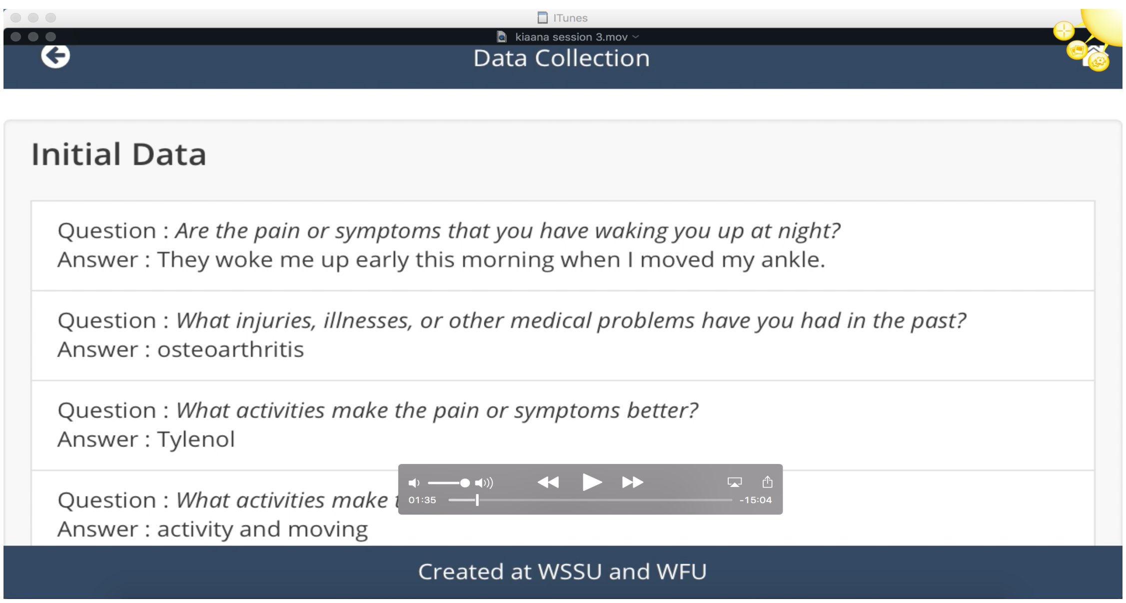


Figure 4.4. Depiction of Data Collection Procedure Using Screencasting Software.

Further actions taken within the mobile application were captured with screencasting software using an application that allowed the mobile device's display to be observed and recorded on a computer screen (Figure 4.4, above). User data collected consisted of *inputs into the application* when deviations from the HOAC II-1 algorithmic sequencing occurred, *rationales for hypotheses generated or decisions made*, the *order and time spent on each step* and *user reflections on needed changes in the evaluation and examination process* that were collected during the debriefing page located within the application.

Justification of the Data Collection and Research Methodology

This study utilized a sequential, intervention-based qualitative approach (QUAL→ QUAL→ QUAL) to explore the overall research question and the sub-questions. The rationale for use of the qualitative data within this study allowed for a detailed understanding of the problem to be developed, specifically how clinical reasoning and procedural schema are affected by a mobile intervention (Creswell, 2012). Further, by noting what scaffolds were most used and how their use changed over time, this researcher was able to make inferences about what scaffolding may be most useful as clinical reasoning is developed.

Within PT, the task-based interview strategies employed in this study have been utilized to allow elicitation of clinical reasoning strategies (Gilliland, 2014; Jensen, et al., 2012). Qualitative investigation in these studies has been used for the purposes of deducing the "complex and unknown processes that occurred during interventions" (Jensen, et al., 2012) using "contextually grounded interviews using role-play of a patient examination" (Gilliland, 2014). More specifically, the task-based interview methodology utilized in this study has been shown to be valid in assessing clinical reasoning in PT students (Chapman, Westmorland, Norman, Durrell, & Hall, 1993). It can also assist in assessing learning (Graham, 1996), and in detecting individuals' thoughts in situations (Davison, Vogel, & Coffman, 1997). Since this type of interview can also be used to evaluate cognitive processes (Blackwell, Galassi, Galassi, &

Watson, 1985), they are appropriate for evaluating the complex cognitive processes that are situated around clinical and diagnostic reasoning (Gilliland, 2014, p. 65).

Further qualitative measures such as video data, user actions during application use, and user analytics or input from application interactions were used to detect possible changes in the sequential organization of the reasoning process, changes in scaffold usage, or changes in clinical reasoning produced by the mobile application. Use of video data in this manner allowed a “fine-grained analysis of the participant’s problem solving and the features [of the application] accessed” during use of the mobile application (Lee & Hollebrands, 2006, p. 257). User entry data obtained during use of the mobile application were utilized to provide trustworthiness to the analysis techniques in corroborating the true impact of the intervention. While these methods have not been used extensively in physical therapy, video-based observation research has been used in medicine since the 1970s (Asan & Montague, 2014). and has been shown to be valuable for evaluating “the impact of computer use and effective use of the computer by physicians during the examination” (Asan & Montague, 2014, p. 3), or “evaluation of complex constructs and interactions in dynamic environments” (p. 6). Further, video data allows for the analysis of person–technology interaction (Pearce, Dwan, Arnold, Phillips, & Trumble, 2009). Finally, these methodologies have been shown to be effective within education for elucidating the thought processes and sequences within problem solving (Lee & Hollebrands, 2006).

Data Analysis Methods

The following section describes how data analysis occurred. First it describes how data as whole were analyzed, how user input data were analyzed, how data collected during interview sessions were analyzed, how video data were analyzed, and concludes with how trustworthiness was ensured.

Qualitative Data as a Whole

After all the qualitative data were transcribed from interviews or placed into a narrative by the researcher, the data for research question one was analyzed with the aid of Atlas TI using a collective case (Research Question 1) or a within and across case (Research Question 2) based approach. This approach was utilized in order to approach allowed the researcher to explore differences between cases and replicate findings across cases (Baxter & Jack, 2008). This methodology was selected so that the researcher could predict similar results across cases, thereby allowing the overall influence of the mobile application on clinical reasoning outcomes to be determined. These influences may depend on factors such as knowledge built by the mobile application, use of mobile application scaffolds, or degree of engagement with the mobile application (Ayres, Kavanaugh, & Knafl, 2003).

User Input Data

Data from user inputs such as user rationale for steps taken out of order or user reflections were analyzed through a thematic analysis approach. The researcher used an inductive methodology (Fereday & Muir-Cochrane, 2006) to assess the utility and influence of the application on clinical reasoning processes. A thematic analysis methodology using an inductive approach allowed the derivation of themes directly from the data, thereby "identify[ing] the nature of the basis of the experience into a meaningful whole" (Saldaña, 2015, citing DeSantis & Ugarriza (2000), p. 176). Using this approach, data were coded into small units of analysis, or codes. From these codes, initial categories were developed. These categories were subsequently connected and condensed in order to identify collective final themes (Fereday & Muir-Cochrane, 2006; Saldaña, 2015; Strauss & Corbin, 1990).

Data Collected During Interview Sessions

Data obtained from task-based interview transcriptions, researcher field notes, and student work were analyzed using both an *a priori* deductive analysis methodology and an inductive data analysis methodology.

Data analysis using an *a priori* deductive methodology. ***Sequence and strategy***. Data from interview sessions was first analyzed utilizing an *a priori* code manual (Table A.3, Appendix K) to guide the data analysis process (DeCuir-Gunby, Marshall, & McCulloch, 2011). The code manual utilized information from the steps in the HOAC II-1 (Rothstein, et al. 2003) and from themes in the clinical decision-making frameworks as outlined by Gilliland (2014) to provide the codes (*a priori*) for analyzing the narrative process of the think aloud interviews related to the order and types of reasoning utilized, respectively. By using these codes, a theory-driven structure was provided that allowed the researcher to identify the sequence (HOAC-II-1) and types (Gilliland) of clinical reasoning strategies that were used. The reliability of the code manual was tested using peer debriefing from the pre-intervention phase (*first task-based interview)* and subsequently revised. The revision was conducted using an inductive coding process to ensure that all participant statements were adequately represented and their essence maintained (Decuir-Gunby, et al, 2011; Creswell, 2012). In performing this analysis, where Atlas TI was used to collapse codes into higher-level categories, to split codes into more representative categories, and to re-define categories, an additional type of reasoning strategy was identified, considering patient factors, which was defined as considering both non-patient identified and patient-identified problems in the reasoning process. A description and definition of the inductive code related to the clinical reasoning strategy that was added is noted in Table A.4, Appendix L.

Once data were coded according to the clinical reasoning process and to the HOAC II-1 framework, they were analyzed using a narrative analysis approach. The narrative analysis approach allowed the researcher to provide an explanation for the "complexity of human action with its relationship of temporal sequences and motivations" Within this analysis, the HOAC II-1, and reasoning strategies expressed by Gilliland (2014) were utilized as a comparative framework to analyze the clinical reasoning sequence and strategies, respectively, expressed by the student in pre and post task-based interviews.

Corroboration of sequence and strategy. Once these data were analyzed and the sequence and strategies were determined collectively, a further analysis was conducted. This analysis corroborated the sequence and strategy in order to look at the interplay between the sequence and types of reasoning employed. This methodology was utilized to describe the integration between the types and order of reasoning strategies used, and the resultant outcomes from the selection of a reasoning strategy. By analyzing data in this way, the researcher was able to elicit data on the changes on reasoning outcomes produced by the mobile application to the sequential orientation to the HOAC II-1, in the types of clinical reasoning strategies utilized, or the outcomes of the clinical reasoning process produced from selecting a particular order or strategy to reason.

Soft scaffolds utilized during the interview process. Data from *pre- and post-task-based interview sessions* was further analyzed to look at the types of supports (soft scaffolds) that were needed/asked for by the participants during the *pre- and post- task* interview process, using a deductive coding methodology (Fereday & Muir-Cochrane, 2006) that employed the *a priori* scaffolding definitions posited by Quintana et al. (2004) (Table 4.3, below).

Table 4.3. Scaffolding Support Definitions from Quintana, et al. (2004).	
Scaffolding support	Definition
Sense making	Relates to the steps the learner goes through in hypothetical deductive reasoning, specifically, generating hypotheses, making comparisons, knowledge support, collecting observations, analyzing data, and interpreting data. May also relate to making the disciplinary strategy evident as the learner proceeds through the process of reasoning.
Process management	Relates to the cognitive load tasks that the learner has to perform when making decisions such as keeping track of hypotheses, data, and results. May also pertain to the organizational strategies that the learner employs such as algorithmic frameworks. Can also related to the guidance given related to the scientific reasoning process by composing the task into an ordered task.
Reflection and articulation	Relates to the support the learner needs for metacognition. May consist of helping the learner to articulate their thought processes, guide the thought process, and allowing the learner to reflect upon decisions made.

Further defined in the deductive coding process was the specific type of support needed related to each category of scaffolding, inferred from definitional types and constructs found in Quintana, et al (2004). From this, three types of sense making and three types of process management scaffolds were further delineated. Sense making scaffolds related to providing discipline-specific knowledge to assist student-participants in understanding terminology or the role of the physical therapist, for planning the intervention to allow participants to plan the discipline specific strategy for problem solving, and for clarifying scientific practice, which related to answering questions about the problem-solving process. Process management scaffolds were: summarizing information, related to the student-participant reviewing or repeating information and seeking confirmation, facilitating organization of work products, related to assisting the participant in remembering the step in the process with which they were engaged, and, finally, handling non-salient routine tasks, which related to students asking for previously obtained information or using their external form to write things down. These categorical and typological coding processes were conducted in order to classify the types of supports (soft scaffolds) that were needed/asked for by the participants during the *pre- and post- task* interview process. By using these definitional constructs, a theoretical basis was provided to assist the researcher in determining how the need for clinical reasoning scaffolds changed with use of the mobile application, what scaffolding may still be required post intervention, and if expertise was developing, indicated by a decrease in the amount or types of scaffolding provided amongst participants.

Data analysis using an inductive methodology A further analysis was conducted on post questions contained within in the first and second interview related to the student-participants' attitudes toward perceived factors that may influence clinical reasoning and decision making. In addition, statements in response to questions in the second interview related to the mobile application's utility/effects were analyzed. Pre-, post- and post-only responses were analyzed by using inductive coding, collapsing into axial codes, and then generating major and minor themes, (Creswell, 2012) aided by Atlas TI. For the purposes of the analysis, a theme was considered to be major if 3 or more participants expressed statements that were congruent with the theme, and minor if less than 3 participants expressed statements that were congruent with the theme. The codes used are noted in Tables A.5 and A.6 (Appendix K). A summary of the interview data analyzed with the methodology and frameworks used, and outputs generated is depicted in Figure 4.5, below.

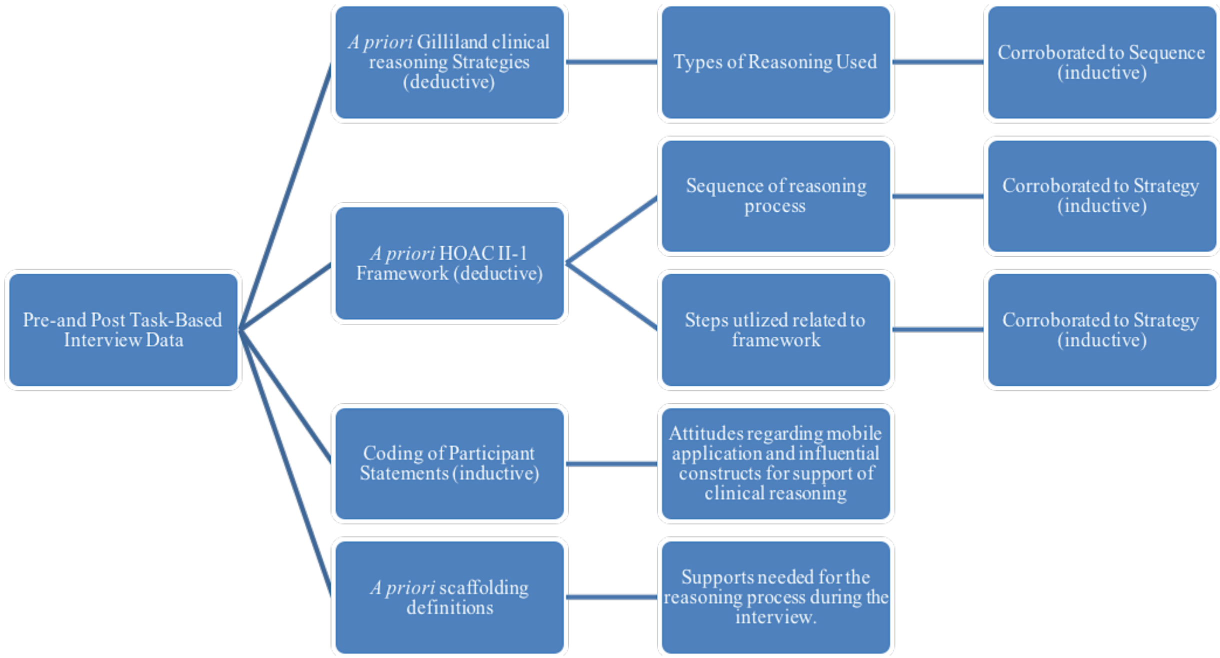


Figure 4.5. Interview Data Analyzed and Outputs.

Video-Based Data

To complement the findings from the data that were input to the mobile application itself, three individuals' video-based data from the second, third, and fourth sessions with the mobile application were purposefully selected for analysis. The individuals selected for this stage of the data analysis were those who had spent the most time interacting with the application, as indicated by mobile application time stamp data from the three sessions following the introductory session. For each of the three active users, and amongst the three users a within-session and across-session approach was utilized for data analysis, with four goals: (1) of detecting changes in the use of soft scaffolding provided by the application across sessions, (2) understanding how the application supported the reasoning process across sessions, and (3) determining whether there were possible obstacles or benefits to scaffolding utilized (4) Implicating need for changes in application design.

For the data collected in this study during mobile application use, each user session was treated as a narrative unit of analysis (Polkinghorne, 1995). Data from each unit of analysis included the various types of data that were collected: annotations of video data and/or screenshots to depict student-participants' work within the application, descriptions of physical gestures or actions undertaken by student-participants while using the mobile application, and analytics from the mobile application (Lee & Hollebrands, 2006).

From each narrative unit of analysis, data related to human activity viewed through a lens of "purposeful engagement" (Polkinghorne, 1995, p. 5) were transcribed in the order in which they occurred from the data sources noted above. Purposeful engagement was defined as "goal-oriented behavior to which effort is focused or directed" following the methodology of Lee and Hollebrands (2006, p. 256). From each goal-oriented behavior, participant actions were coded into the type of goal-oriented behavior pursued related to either the use of algorithmic sequence of the HOAC-II-1 and/or use of soft scaffolds within the mobile application. For the purposes of this study, a HOAC-II-1 or scaffolding based goal-oriented behavior was identified as: (1) pursuing a goal via action or thought related to the HOAC II-1 framework by clicking/tapping on a step or entering data into the application, (2) pursuing a goal via action or thought related to accessing soft scaffolds in the application, (3) engaging in articulation or reflection by entering additional data, (4) entering a rationale for the decisions made, or (5) engaging with process management features of the application.

Data related to the goal-oriented behavior were further analyzed by the HOAC II-1 step pursued as defined in Table 3.1. To further analyze the reasoning process, behavior related to the HOAC II-1 framework was coded by using the codes defined in the *a priori* coding manual (out of HOAC order, in HOAC order) to determine whether the sequence of the algorithm was being followed. Any out-of-sequence event was transcribed from the video data and the user data (which consisted of the rationale associated with that event); this transcription was subsequently analyzed using inductive coding. Using the out of order sequences, a further analysis was conducted, to determine what changes needed to be made within the mobile application by attributing if the application caused the out of order sequence.

An additional analysis from the coding of the goal-oriented behavior related to the scaffolding features that student-participants accessed. These behaviors were further coded to define the type of soft-scaffolds utilized as related to the scientific reasoning scaffolding framework that were defined during application design (Quintana, 2004) (Table 3.2).

The goal-oriented behaviors were further analyzed to identify what features were accessed, and when, during the reasoning process by corroborating the scaffolding feature to what step in the HOAC II-1 was being pursued at that time. Similar to Lee and Hollebrands (2006), data on which application features were accessed were coded as supportive or non-supportive. Application features were coded as supportive if they assisted the participant in accomplishing the clinical reasoning goals, in proceeding through the algorithmic framework, and in working toward the end point of establishing the hypothesis and making a decision toward treatment appropriateness. Finally, correctness of the hypothesis and treatment appropriateness as well as rationales were corroborated with the sequence and support needed using a collective case approach. The purpose of this analysis was to detect whether the participant's orientation to the HOAC II-1 framework, use of a particular reasoning strategy, or need for support for clinical reasoning had an effect on their hypotheses generated or their decisions and rationales towards treatment and treatment appropriateness. A summary of how these video data and mobile application data were analyzed is depicted in Figure 4.6, with the frameworks utilized and outputs obtained.

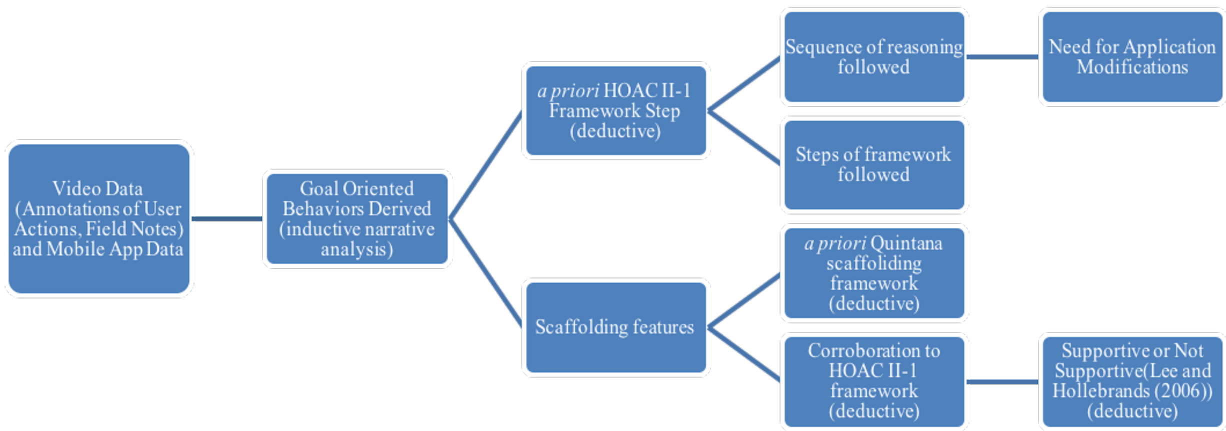


Figure 4.6. Video and App Data Analyzed with Frameworks and Outputs.

Trustworthiness

Several methods were utilized to ensure the trustworthiness of the qualitative findings (Creswell, 2012). First, triangulation was used to corroborate findings between several types of qualitative data: task-based interview session data (field notes, student worksheets, and transcriptions), as well as application session use data (user input transcriptions, video data, time-based analytics, diagnoses, and clinical decisions reached) (Creswell, 2012). Secondly, peer debriefing was used to test the reliability of the code manual and revise it based upon an inductive coding process to ensure that all participant statements were adequately represented and their essence maintained (Creswell, 2012; DeCuir-Gunby et al., 2011). Finally, member checking was used by having the student-participants review the transcriptions for accuracy, and by ascertaining whether the student-participants agreed with the themes derived from task-based interviews, researcher field notes, video-based data, data entered into the mobile application, and the overall findings.

Conclusion

Using the qualitative approach and conceptual framework described above, an understanding was developed regarding the mobile application's impact on student-participants' clinical reasoning ability. Specifically, the study investigated changes in PT students' ability to develop a procedural schema to use the algorithmic process as defined by the HOAC-II-1; generate a diagnostic hypothesis and make a determination towards treatment appropriateness and rationale; and use more advanced clinical reasoning. The methods of this study have been utilized previously in education, physical therapy, and medical research. By answering these questions, the study provides the first evidence in PT for the utility of mobile applications for student learning of these complex processes.

CHAPTER FIVE: FINDINGS RESEARCH QUESTION ONE

The purpose of this study was to explore and describe the impact of a scaffolded mobile application on physical therapist (PT) students' scientific clinical reasoning process. The mobile application was designed in congruence with the Hypothesis Oriented Algorithm Framework II-Part 1 (HOAC II-1) and included design elements from the Scientific Reasoning Framework Model. This chapter will explore in particular, results related to Research Question 1, noted below.

Research Question 1

How are PT student-participants' strategies and sequence of clinical reasoning and hypothesis generation influenced by a mobile application's scaffolding of the HOAC II-1 framework?

Collective Case Findings: Research Question 1

For the purposes of this chapter, two different types of findings related to research question one will be presented, using a collective case approach, as findings were similar within cases, regardless of student-participant demographics. First presented are pre- and post-intervention findings, which relate to how clinical reasoning and perceptions of clinical reasoning were affected by the mobile application. Secondly presented are the post-intervention only findings, which relate to the impacts of the mobile application on clinical reasoning and student-participants' recommendations for application re-design. Finally, the chapter will conclude with a summary of the findings related to research question one.

Trustworthiness

Trustworthiness for the findings provided in this chapter was ensured by member checking, where each participant agreed to the findings related to sequence and types of reasoning employed, by stating, “I agree,” or “That’s what I did.” Further, trustworthiness for themes derived in the chapter was ensured through peer debriefing and member checking between an expert physical therapist, or between the participant and the researcher, respectively, which revealed statements such as “That seems accurate,” and “I agree with the analysis.”

Findings from the Pre- and Post-Intervention Task Based Interview Process

This section will present the findings attributable to the use of the mobile application related to changes in clinical reasoning as derived from the *pre- and post- intervention interviews*, *participant form*, and *researcher field notes*. In considering pre-and post- intervention data, five different findings related to changes in clinical reasoning produced by use of the mobile application emerged from participant data. These are:

Finding 1) Participants used lower order reasoning strategies prior to intervention and higher order reasoning strategies after intervention.

Finding 2) Participants typically needed less scaffolding support for the reasoning process post-intervention, however some scaffolds were still needed.

Finding 3) The narrative order of the reasoning process changed from less-ordered to more ordered after the intervention, and less cues were needed for the sequence of the reasoning process.

Finding 4) There were improved clinical reasoning outcomes related to making a diagnosis post intervention. This outcome resulted from an increased ability to utilize a higher order reasoning strategy and improved sequence of the reasoning process. However, some errors persisted related to making treatment decisions.

Finding 5) Participants’ perceptions of influential constructs that facilitate clinical reasoning either remained constant or changed.

Each of these findings will be relayed subsequently in their own sub-section.

Finding 1): Participants Used Lower Order Reasoning Strategies Prior to Intervention and Higher Order Reasoning Strategies After Intervention.

Within this section, the types of reasoning strategies used by participants in their interview processes will be relayed. This section first presents the deductive and inductive data analysis methodology utilized to produce the findings. Secondly presented are the pre-intervention clinical reasoning strategies utilized by participants. Third, and finally, the post-intervention clinical reasoning strategies utilized by participants is relayed and contrasted to the pre-intervention findings in order to highlight changes in the clinical reasoning strategies utilized by participants.

Data analysis process to determine strategy use. Interview data were deductively and inductively coded to determine which types of clinical reasoning strategies were utilized by student participants while reasoning during the interview processes. Deductive coding was guided by the utilization of the clinical reasoning types outlined by Gilliland (2014), that outline the progression of reasoning in PT students on a continuum, where students progress from the use of trial and error to the ability to employ pattern recognition as a strategy. The reasoning strategy, reasoning about pain, defined within the framework, is maintained equally by novice practitioners and experts, and therefore is generally regarded by Gilliland (2014) to be contiguous with the other strategies utilized. These strategies are outlined in Table 5.1., below.

Table 5.1. Clinical Reasoning Strategies, Adapted from Gilliland (2014).

Theoretical Framework Term	Definition
Clinical Reasoning Strategy: Trial and Error	No initial plan for reasoning or hypothesis generation; reasoning appears randomly generated; no clear movement from one structure to another

Table 5.1. (continued).

Clinical reasoning Strategy: Following Diagnostic Protocols	Trying to recall information from class; using evaluation forms from class
Clinical reasoning Strategy: Rule-in, Rule-out	Beginning with one or more hypothesis, reasoning about that hypothesis, and moving on to another hypothesis
Clinical reasoning Strategy: Hypothetical-Deductive	Generating hypotheses and using an organized plan of testing to rule out or rule in. Demonstrates ability to shift hypotheses when faced with contradictory information.
Clinical reasoning Strategy: Pattern Recognition	Making a primary hypothesis to describe the patient condition from prior experience, or from a matching patient description from previously encountered patient case. Using examination to confirm a hypothesis and explaining data findings in light of diagnosis.
Clinical reasoning Strategy: Reasoning about Pain	Using the pain description and aggravating/relieving factors to guide reasoning. Considering chronicity, severity, and irritability. Contiguous with other strategies and utilized equally by novice and expert practitioners.

In addition to utilizing the reasoning strategies expressed by Gilliland (2014), interview data were also analyzed using an inductive methodology to determine if there were types of clinical reasoning strategies not expressed in the framework that were used by participants while reasoning. This process resulted in an added inductive clinical reasoning theme, reasoning about patient related factors such as patient identified and non-patient identified problems. This theme was defined as considering patient problems, which included statements from student-participants when they included issues identified in the medical record, problems expressed by patients, or issues identified during examination in their reasoning process. This code, however, did not consider how participants integrated these problems into the clinical reasoning process. The integration of these problems into the reasoning process will further considered when discussing the integration of strategy and sequence (Finding 4) later in the chapter.

Collective case analysis of types of reasoning strategies used pre-application use. The types of reasoning strategies utilized by student participants during their *pre-task-based interview* are represented in Table 5.2, below, indicated by an X and shading.

Table 5.2. Summary of Types of Reasoning Strategies Used Pre-Application Use.

Partici-pant	Trial and Error	Following Protocol	Rule in/Rule Out	Hypothetical Deductive	Pattern Recognition	Reasoning About Pain	Reasoning About Patient Factors
Sara	X	X	X			X	X
Bryan	X		X			X	X
Marcus	X					X	X
Shannon	X					X	X
Kerry			X			X	X
Charlotte	X					X	X

Taking into account individuals' reasoning strategies during their pre-intervention *task-based interviews*, four thematic elements emerged related to Finding 1. These themes were: 1) Student-participants initially used multiple reasoning strategies, 2) Student participants initially used strategies that are equally used by both novices and experts, 3) Student participants used lower-order, less sophisticated reasoning strategies primarily used by novices, and 4) Student participants did not use reasoning strategies used primarily by experts. Each of these themes will be described subsequently with supporting statements.

Theme 1). As exemplified in Table 5.2, student-participants utilized between three to five different reasoning strategies in their pre-intervention interview. The use of multiple strategies for reasoning is consistent with findings regarding inexperienced (novice) practitioners, who do not have a singular, focused strategy for clinical reasoning.

Theme 2). All participants utilized strategies that are utilized equivalently by novices and experts in their clinical reasoning processes. These strategies were reasoning about pain, and reasoning about patient factors. First, in considering reasoning about pain, two participant statements, one from Bryan, and the second from Marcus, typify statements made by other participants when considering pain in clinical reasoning. Bryan stated:

> "If it's coming on all of a sudden, she doesn't really have a reason for it, I want to find out everything I can about her pain to see, like I said, what aggravates it, what alleviates it."

Equally expressing the theme, Marcus stated:

> "I asked about a pinch nerve just because it was something that happened over time, it wasn't a steady thing, so I figured her nerve could be rubbing, causing pain as she walked…. I don't know if this is right but, I have heard of parts where high blood pressure and cardiovascular issues can manifest this pain."

In considering the other strategy utilized by every student, reasoning about patient factors, two statements, one from Shannon, and one from Kerry, effectively express this reasoning strategy. Shannon stated:

> "Well, I wanted to know about if she had a more active or sedentary lifestyle, just because from what I've learned typically, individuals who are more sedentary will typically have problems, I guess, with posture. I guess muscles that deal more with posture and can affect gait…. My initial hypothesis, not necessarily taking all of the factors that I have out, was first just degenerative changes, just because I knew that she was 60."

Further providing evidence for the use of this strategy, Kerry expressed:

> "Looking at her age, number one. She's an older, well she would be considered an older adult, and she's female, so she may have systemic ... What am I trying to say? Anyway,

musculoskeletal deficiencies just in general, because most older, well the older population they have either osteoporosis or some kind of muscular atrophy."

Theme 3). Further considering the types of primary clinical reasoning strategies utilized, participants used lower-order, less sophisticated strategies that are typically used by novices when performing clinical reasoning. These consisted of a trial and error strategy only (Marcus, Shannon, and Charlotte), a combination of trial and error and rule in/rule out strategy (Sara and Bryan), or a rule in/rule out strategy only (Kerry). Supporting statements for each type of strategy will presented subsequently beginning with trial and error and concluding with rule in/rule out.

For those participants who chose a trial and error strategy, three participant statements best typify this type of strategy, one from Sara, one from Bryan, and one from Marcus. Sara alludes to this strategy when she stated:

> "I'm still going to go with blood clot just because I don't know enough about the vascular system. Especially the hyperlipidemia, I don't know what that can have an effect on with the vascular system because we haven't gone in that kind of detail with that. I don't think it's an orthopedic problem at this point."

Further exemplifying a trial and error strategy is a statement from Bryan who stated: "I just can't think of what tests I would want to come up with any other theories," and a statement from Marcus when he stated, "That's the problem, I'm not completely sure…. This is such a shot in the dark."

Statements that relate to the rule in/rule out strategy utilized by participants were expressed by two participants, Bryan and Kerry. Bryan stated:

"Oh. At this point I'm looking to see where her pain is coming from, whether it's actually in her ... if there's something with her lower extremity going on or if it's being referred from somewhere else." "I guess I ... I was gonna say sit to stand, but I don't really think so, because it's helpful to rule out other things."

Further supporting the use of this strategy is Kerry's statement. She stated:

"I am trying to rule out some things. I definitely ruled out her muscle strength and range of motion, except for the dorsiflexion, but her strength in her ankle was a little weaker compared to the hip and knee. So, that's telling me that it could be a distal issue, as far as in her foot, or her ankle rather."

Sara, in contrast to others, was the only one to utilize a following protocol strategy, in combination with her other strategies. This strategy use is characterized by the following statement:

"I'd still do a special test even though they all came back negative…. I think they're just as effective in helping you determining what's wrong, as well as the palpation. I wouldn't want to leave out any of those parts of my testing procedures."

Theme 4). Finally, no evidence was found in the narratives of any participant for the use of hypothetical deductive or pattern recognition strategies. These strategies are higher order, more advanced reasoning strategies, generally utilized by expert practitioners.

Across case analysis of types of reasoning strategies used post-application use. Presented in Table 5.3 are the categorical types of reasoning strategies utilized by participants in their *post- task-based interview*, indicated by an X and shading.

Table 5.3. Summary of Types of Reasoning Strategies Used Post-Application Use.							
Partici-pant	Trial and Error	Following Protocol	Rule in/Rule Out	Hypothetical Deductive	Pattern Recognition	Reasoning About Pain	Reasoning About Patient Factors
Sara					X	X	X
Bryan				X		X	X
Marcus				X		X	X
Shannon		X	X			X	X
Kerry				X		X	X
Charlotte		X			X	X	X

In considering the effects of the mobile application on the strategies utilized to reason clinically during the *post task-based interview*, three main themes related to Finding 1 emerged: Theme 1) Student participants utilized fewer or an equivalent number of reasoning strategies after intervention, Theme 2) Most participants were able to utilize more expert, higher order reasoning strategies after intervention, and Theme 3) Student-participants maintained the use of two reasoning strategies: reasoning about patient factors and reasoning about pain after intervention. Each theme will be presented subsequently with statements that support that theme.

Theme 1). Regarding at the number of reasoning strategies used within the reasoning process, in all but two cases, (Shannon and Charlotte), student-participants utilized fewer (Sara and Bryan) or an equivalent number of clinical reasoning strategies (Marcus and Kerry), as exemplified in Table 5.3, above. This reduction in the number of clinical reasoning strategies used may indicate a progression in clinical reasoning expertise, since experts tend to use less strategies when performing clinical reasoning. Of the individuals that increased in the number of reasoning strategies (Shannon and Charlotte), the increase in use of number of strategies was due to the fact that they each made one statement that alluded to using the following protocol strategy, related to visualizing the framework utilized within the mobile application, during their *post think-aloud interview*. This type of strategy use is exemplified by Charlotte when she stated:

> “Mostly, I'm recalling going through this process a few times during this trial [with the application] and then also in classes, thinking with the questions that ... general questions that we need to ask during an evaluation.”

and Shannon, when she stated, “[I decided to ask questions of the patient] just from previous cases that I've done within the app.”

Theme 2). Another change produced by the mobile application is the ability of all student-participants to utilize more sophisticated, higher order clinical reasoning strategies, consistent with the development of expertise in reasoning. In the *initial task-based interview*, the majority of participants used a number of clinical reasoning strategies including, trial and error or a combination of trial and error and rule in/rule out clinical reasoning strategies, reasoning about pain, and reasoning about patient factors, as previously discussed.

Subsequent to use of the mobile application, every student-participant demonstrated progression in their ability to utilize a higher-order clinical reasoning strategy. For all student-participants, except for Shannon, this meant progressing from the lowest level of clinical reasoning, trial and error, to utilizing the clinical reasoning strategies more utilized by experts, namely, hypothetical deductive (Bryan, Marcus, and Kerry) or pattern recognition (Sara and Charlotte). These assertions will be supported with participant statements, first providing evidence for the use of hypothetical deductive strategies, and then providing evidence for the use of pattern recognition strategies.

In considering statements that exemplify a hypothetical deductive strategy, two participant’s statements are presented. First, Bryan stated:

"I would say she has maybe a DVT or some sort of vascular insufficiency…. Because of my initial hypothesis, I wanted to test out her vasculature. Vital signs good to know. Then I wanted to test out for arterial insufficiency and anything else that could point towards a vascular problem."

Further providing evidence of the use of this strategy, Kerry stated,

"Okay. I would think it would be arterial because she has pain when she's elevated her legs. It's one of my initial hypotheses. Some kind of deficit with her arterial peripheral arteries. The blue toes, venous because she may not like ... Her veins may not drawing the blood if she's having deoxygenated blood in her feet…. Okay, my initial hypotheses would be arterial deficiencies and venous deficiencies; and because she's had a heart attack, so she has congestive heart failure already so that could indicate…that could be another indicative factor…. I chose Stemmer for the venous to test her venous flow. Rubor dependency, I chose it to test her arterial functioning. ABI, arterial functioning as well."

Statements that exemplify a pattern recognition strategy were made by Sara and Charlotte. Sara stated:

"One thing that I'm thinking is there could be something with the arterial system, especially being high cholesterol, high blood pressure, and diabetic, that's gonna put more strain on the arterial system…Yes, arterial, and then again, we haven't gotten in the stuff with the venous and the arterial system but the fact that being in a dependent position makes it feel better, in my mind, that makes me think that it's not a venous issue."

Additionally, Charlotte stated:

"I've identified the history of myocardial infarction and hyperlipidemia probably leading to some arterial insufficiency causing restricted blood flow to the lower extremity, which is causing the pain, and also presenting with the symptoms of increased pain with walking long distances and elevation."

While Shannon did not use a hypothetical deductive or pattern recognition strategy, she did, however, progress in her clinical reasoning strategy from using a trial and error strategy in her *pre-task-based interview* to using a rule in/rule out strategy. This reasoning strategy is best exemplified by Shannon when she states:

"I ruled out the venous insufficiency just because with elevation that the pain increased instead of decreasing. Usually if it's venous, it would decrease. There's no swelling, so I wasn't thinking lymphedema…. but it's like I've out ruled three."

Theme 3). Finally, in considering the clinical reasoning strategies utilized by every participant, it is interesting to note that, consistent with both novice and expert practice, examples of reasoning about patient factors and reasoning about pain continued to be interspersed within each participants' reasoning strategies from their *pre-* to *post task-based interviews.* The use of these continued strategies for reasoning resulted in two student participants (Kerry and Marcus) maintaining the number of strategies utilized within their *pre and post task-based interviews*. To support the assertion that these strategies were evident in participants' narratives, supporting statements for reasoning about patient factors and reasoning about pain will be provided subsequently, starting with reasoning about patient factors and concluding with reasoning about pain.

Representative statements that exemplify reasoning about patient factors are given by Shannon when she stated: "Well, I already said with the patient history of diabetes and then hyperlipidemia as well myocardial infarction would diminish [health status]," and when Bryan stated, "Then past history to see if she's had a history of vascular problems to see if that can play a part in the issue or not."

Finally, in considering the strategy reasoning about pain, two participants' statements are given, Kerry and Bryan. Kerry stated:

> "She indicated that she was having pain, so I want to know where it was, so I asked about the location. I asked for the sensation, so she could describe the pain for me. I asked for the duration because depending on how long it's been, it could indicate if this is acute pain, or chronic pain, so what just happened or it did happen."

To further exemplify this type of strategy, Bryan stated: "Well, I wanted to know specifically where her pain was because I can't make decisions based on just lower extremity in general."

Finding 2). Participants Typically Needed Less Scaffolding Support for the Reasoning Process Post-Intervention, However Some Scaffolds Were Still Needed.

Within this section, findings related to the number of soft scaffolds required for student participants to complete the reasoning process during the two *task-based interviews* will be relayed. This section first presents the deductive data analysis process utilized to produce the findings, which utilized the scaffolding strategies posited by Quintana et al. (2004). Secondly presented are the scaffolds required by participants to complete the *pre-intervention task-based interview*. Finally, scaffolds required by participants to complete the *post-intervention task-based interview* will be communicated, and a summary of findings related to changes in the use of scaffolds needed by student participants will be presented.

Data analysis process. Results in this section are derived from a deductive coding methodology (Fereday & Muir-Cochrane, 2006) that employed the *a priori* scaffolding definitions posited by Quintana et al. (2004) (Table 5.4, below).

Table 5.4. Scaffolding Support Definitions from Quintana, et al. (2004).

Scaffolding support	Definition
Sense making	Relates to the steps the learner goes through in hypothetical deductive reasoning, specifically, generating hypotheses, making comparisons, knowledge support, collecting observations, analyzing data, and interpreting data. May also relate to making the disciplinary or scientific inquiry strategy evident as the learner proceeds through the process of reasoning.
Process management	Relates to the cognitive load tasks that the learner has to perform when making decisions such as keeping track of hypotheses, data, and results. May also pertain to the organizational strategies that the learner employs such as algorithmic frameworks. Can also related to the guidance given related to the scientific reasoning process by composing the task into an ordered task.
Reflection and articulation	Relates to the support the learner needs for metacognition. May consist of helping the learner to articulate their thought processes, guide the thought process, and allowing the learner to reflect upon decisions made.

Additionally, defined in the deductive coding process, was the specific type of scaffold needed by participants related to each category of scaffolding that were inferred from definitional types and constructs found in Quintana, et al (2004). From this, three types of sense making and three types of process management scaffolds were further delineated typologically. These typological scaffolds will be described next.

Sense making scaffolds delineated were related to knowledge support, planning the investigation, or for clarifying scientific practice. Knowledge support was defined as providing discipline-specific knowledge to assist student-participants in understanding terminology, obtain needed factual information, understanding the role of the physical therapist. Planning the intervention scaffolding involved the provision of cueing related to assisting in the discipline specific strategy for problem solving. Finally, the scaffold, clarifying scientific practice, related to answering questions about the problem-solving process. Process management scaffolds were: summarizing information, related to the student-participant reviewing or repeating information and seeking confirmation, facilitating organization of work products, related to assisting the participant in remembering the step in the process with which they were engaged, and, finally, handling non-salient routine tasks, which related to students asking for previously obtained information. These categorical and typological coding processes were conducted in order to classify the types of supports (soft scaffolds) that were needed/asked for by the student-participants during the *pre- and post- task* interview process, to detect changes in the soft scaffolds needed by student-participants as an indicator of possible developing expertise.

Collective case themes related to soft scaffolds needed for clinical reasoning pre-application use during the interview process. During the *pre-task-based interview*, student-participants relied extensively on soft scaffolds to generate clinical reasoning related to sense making and process management, and two themes emerged related to Finding 2. These themes were that: 1) Two categorical types of soft scaffolds were needed to support the reasoning process during the *pre- task-based interview*, namely, process management and sense making, and that 2), Various types of process management and sense making scaffolds were needed to support the clinical reasoning process. These scaffolding strategies will be further elucidated in the following paragraphs, by providing supporting statements for the types of scaffolding strategies utilized by participants during their task-based interview in relationship to the typology used and the number of times they were required.

Soft scaffolds for process management utilized by student-participants consisted of three different types: summarizing information, handling non-salient, routine tasks, and facilitating organization of work products. These soft scaffolds were utilized by all student-participants except for Bryan, and the types of support needed varied. For example, Sara, Kerry, and Charlotte required scaffolding for summarizing information (one cue during each participant's *pre- task-based interview*), exemplified by Sara, when she stated, "Yeah, I think that says on here that yeah, the pain's not associated with a cause," and by Kerry, when she stated, "Where is [the pain], oh it's in the calf." Another participant, namely Marcus, required scaffolding for facilitating organization of work products (one cue), exemplified by Marcus's statement, M: "What was the question again, I'm sorry? I: Problem list." Finally, Shannon required scaffolding for handing non-salient, routine tasks (two cues), with the examiner reminding her of data that she had asked for previously, and typified by the statement, I don't think so. I should probably write down this."

Sense making soft scaffolds were also utilized by all participants, however there were similarities and differences among participants. Congruence was found amongst all participants in the need for extensive assistance for planning the investigation, where Sara required six cues, Bryan, Kerry, and Shannon each required five cues, Marcus required seven cues, and Charlotte required four cues. This scaffold was provided by the interviewer during the reasoning process to assist the student-participants in formulating a plan for the reasoning process, as exemplified by cueing for the steps in the process by the interviewer. This scaffold will be further exemplified in Finding 3 by highlighting the number of cues needed. However, within this section, two exemplars are provided, one from Sara and one from Charlotte that are representative of the cueing provided during the *pre-task-based interview*.

In Sara's case, the following exchange took place during the interview process related to cueing for the steps of the process: "Sara: As far as continuing my evaluation with her, I would move in to an objective exam. Interviewer: Okay, all right. What patient problems have you identified currently?" A similar exchange was conducted with Charlotte and is exemplified by the following statement:

> Interviewer: Okay. What would you do now with the information you have collected?
>
> Charlotte: With this information, I'd probably want to start with finding out some range of motion as well as active and passive as far as if either one presents with the pain that she's been feeling. Also, trying a few other tests and activities that are not walking to see if we can simulate the pain in any other situation. Also, just inspect the area.
>
> Interviewer: All right. What patient problems have you identified currently?

Considering other sense-making scaffolds utilized by participants, most participants utilized knowledge support, related to the provision of factual information related to the knowledge of the discipline, where Sara required three cues and Marcus, Shannon and Charlotte each required one cue. This scaffold is exemplified by three statements, one from Marcus, one from Shannon, and one from Sara. The first statement, from Marcus, was: "Interviewer (I): Her past medical history that you asked about was she's got a history of myocardial infarction, diabetes, and hyperlipidemia. Marcus (M): What was the last one? I: Hyperlipidemia, high cholesterol." The second statement from Shannon was: states, "S: "You said hyper-I: Lipidemia. S: Lipidemia. I: As in increased-S: Fat in her blood cells? I: Yes." Third, and finally, Sara stated: (S): What was that last one? Interviewer(I): Hyperlipidemia. S: What's that? I: High lipid levels in her blood.

Finally, thinking about supports utilized in a singular case (Charlotte, who required one cue), the scaffold for clarification of scientific practices was needed, which was supported by Charlotte's statement: "Problems that he has…are you just referring to like symptoms that he has right now? I: Or things you have identified through examination that she has."

Collective case themes related to soft scaffolds needed for clinical reasoning post-application use during the interview process. Post intervention, three themes emerged related to Finding 2, namely that 1) Participants still required soft scaffolds for process management and sense making, 2) The need for sense making scaffolds was reduced in the majority of student-participants, and 3) There were differences in the typologies of scaffolding needed by participants for process management and sense making post-intervention. These three themes will be further illustrated subsequently, starting with sense making and concluding with process management. These themes will be supported by use of statements from participants and by enumerating the number of times that the cues were required to illustrate changes in scaffolding support needed post-application use.

Collective case summary for finding 2 related to soft scaffolds needed for clinical reasoning pre- and post-application use. ***Sense Making.*** Following use of the mobile application, changes in the need for sense making soft scaffolds for completing the reasoning process in the *post task-based interview* were related to decreasing the need for: 1) soft scaffolds used for planning the examination, and 2) knowledge support, in all but two participants, and 3) clarifying scientific practices in one participant (Charlotte). The decreased use of these scaffolds may be indicative of a developing expertise and knowledge base.

In the case of soft scaffolds needed for planning the examination, every participant still needed cueing, with Sara, Bryan, and Charlotte needing one cue, Marcus and Shannon needing three cues, and Kerry needing two cues. However, the number of cues required were reduced by at least two or more cues in each participant. Quotes supporting the need for this type of scaffold are exemplified by the exchange between the interviewer and Marcus below:

> "Interviewer: Okay. All right. So now, what would you do with the information that you have collected?
>
> Marcus: By what tests would I run?
>
> Interviewer: That's part of it. So, you'd run some tests, and then, what patient problems have you identified?"

Further exemplifying this type of exchange is present in Shannon's narrative by the following exchange:

> "Interviewer: Now, what would you do with the patient, with the information you've collected from the patient?
>
> Shannon: I would probably run some tests.
>
> Interviewer: Okay, so we'll get to that in a minute. What patient problems have you identified?"

Another change noted in the need for soft scaffolds after mobile application use (in most student-participants) was the need for knowledge support. Scaffolding for knowledge support was eliminated in in Charlotte and Shannon, decreased in Sara (two cues needed), equivalent in Marcus (one cue needed), and not utilized by Bryan (pre or post). Examples of use of this type of scaffold are provided by the following statements from Marcus and Sara, respectively, when he stated, "Can I refer her…Can I do both?" I: Yes, you can," and when she stated, "Heart auscultation, you hear an S1 and S2. S: Is that good? I: Lub dub. S: Okay. I: So, it's normal. S: Okay, so no murmur."

In contrast, Kerry had an increase in the need for discipline-specific knowledge support during her *post task-based interview*, requiring five cues, which may have been as a result of differences in cognitive load provided between the application and the interview, resulting in difficulties with recall. The support provided related to the interviewer needing to relay the specific names of tests utilized to test the venous or arterial system, due to Kerry's ability to remember how to perform the tests, but an inability to remember the names of the tests. This need for this type of support is evidenced by two statements from Kerry when she stated: "K: I'm blanking. As far as test go, the name of the test. I: Describe the test to me. K: Okay. I don't know. It's like a skin quality test." In another instance Kerry stated:

> "I'm blanking. I want to do some arterial tests. I: Okay. Let's talk about arterial tests. K: Yes. I: All right. Arterial tests. Do you want me to be more specific than that or do you just want to go with general arterial tests? K: We would be specific because we could weed out some things if she's positive or negative on some tests. I: Okay. What specifically do you want to know? K: I want to know if she's getting adequate blood flow to her limbs. I: Are you thinking maybe something like pulses or ABI, or something like that? What are you thinking? K: Yes. We could take the ABI."

The last change noted in the need for sense making scaffolds was a reduction in the need for support related to clarification in scientific practices was also noted in Charlotte, who did not require this scaffold post-intervention.

Process Management. For the majority of participants, process management scaffolds were still required to assist in the reasoning task, due possibly to the high cognitive load present in the task-based interview process. Changes in the process management soft scaffolds from the *pre- to post task-based interview* were highly variable among participants, and most participants experienced changes either in the type or number of process management soft scaffolds needed for reasoning.

In further considering the changes in process management scaffolding utilized, Sara, Marcus, and Shannon had differences in the types of scaffolding used from pre to post intervention, with Sara and Kerry requiring one and two cues for summarizing information, Sara and Marcus requiring one cue each for handling non-salient routine tasks, respectively, Kerry requiring two cues for summarizing information, reflecting an increase in need for this support, Shannon requiring one cue for facilitating organization of work products, and Charlotte eliminating the use of these scaffolds. No change was found in Bryan, as he did not use these scaffolds pre or post intervention. An example of facilitating non-salient routine tasks (management of cognitive load), is stated by Marcus as follows: M: "Multiple comorbidities. What have I said? I: You said low physical activity, multiple comorbidities," The cue for facilitating organization of work products (reminding the participant of the step in which they were engaged) is exemplified by Shannon (requiring one cue), when she stated, "I forgot about, what am I asking you for? I: It says describe the initial information that you would collect." Finally, the need for summarizing information is exemplified by the following exchanges: "You said elevated, exercise makes it worse, and then rest relieves the pain? I: Rest and dependent positioning." and "She describes the pain as cramping in nature and aching in nature. K: She said it was cramping and achy? I: Yes, cramping and achy."

Finding 3). The Narrative Order of the Reasoning Process Changed from Less-Ordered to More-Ordered After the Intervention, and Less Cues were Needed for the Sequence of the Reasoning Process.

Within this section, the sequence of the reasoning process used by student-participants during their interviews will be relayed. This section first presents the narrative deductive data analysis process utilized to produce the findings. Secondly presented are the pre- and post-intervention sequences of clinical reasoning utilized by participants and participant statements from *pre-and post- task-based interviews* that exemplify steps in the HOAC-II-1 framework. Finally, a summary of changes in the sequential order of the reasoning process utilized by participants will be presented.

Data Analysis Process. The data analysis process utilized a scientific clinical reasoning algorithmic framework, the HOAC-II-1 as a comparative lens from which to infer the stepwise process followed by student-participants during the two interviews. These categories and definitions are outlined in Table 5.5., below, in the order expressed within the framework.

Table 5.5. HOAC II, Part 1 Framework Definitions Used in This Study.

Step in the Framework	Definition
Collect Initial Data	Collecting information using questioning/interviewing including: the patient history, patient expectations, and patient's observations about their condition. May include reviewing the medical record/case history.
Generate Patient-Identified Problems List	Recording a patient report of the problems that describe reasons for coming to physical therapy, listing patient-identified limitations, listing functional impairments, and patient concerns about future limitations.
Formulate Examination Strategy	Determining the need for further information based upon initial data collection and patient-identified problems. The PT identifies what initial hypotheses exist and what tests are needed to confirm or deny these hypotheses. The PT provides a rationale for generated hypotheses.

Table 5.5. (continued).

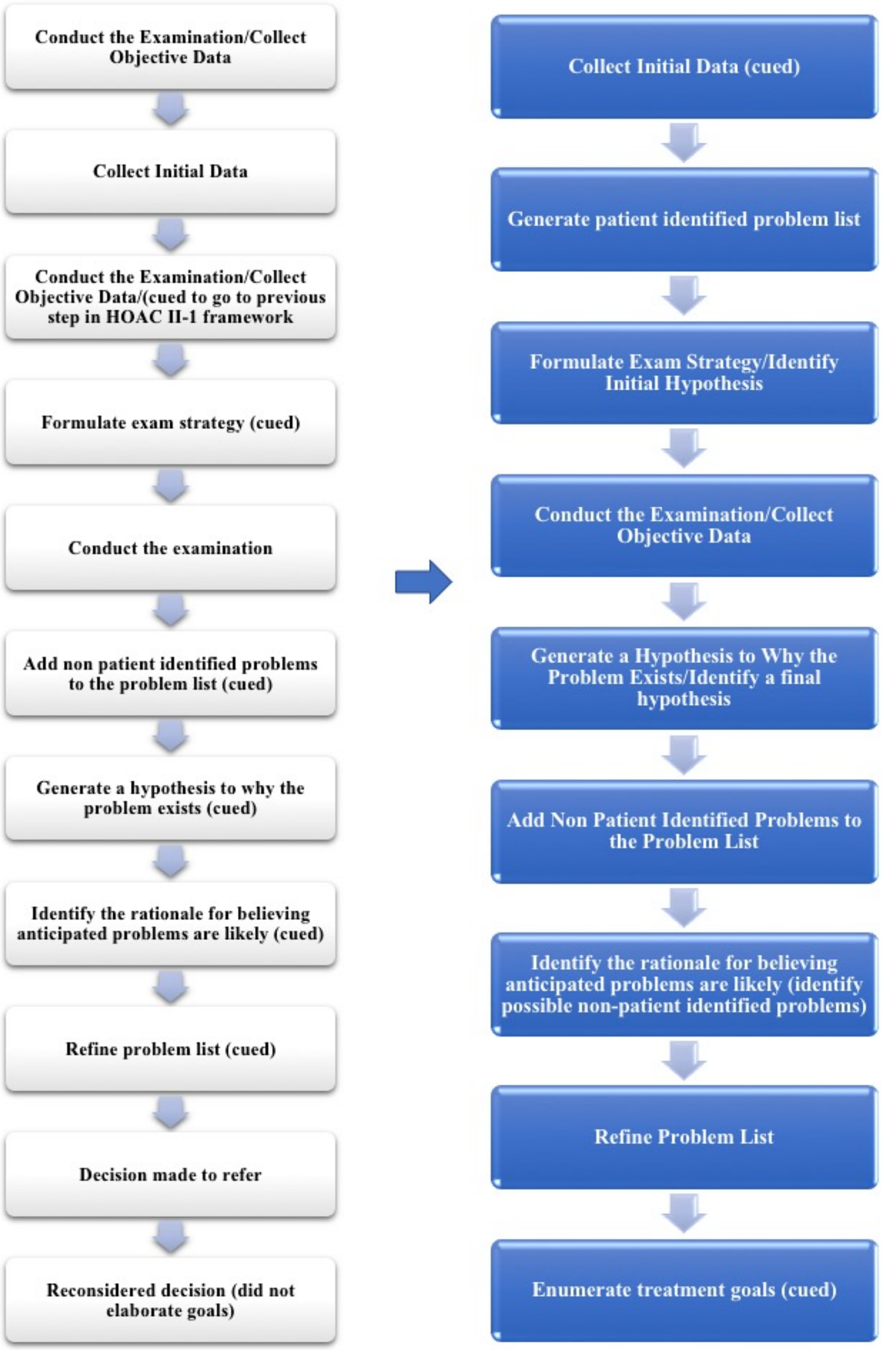
Consultation if Needed	The PT seeks outside assistance or support from other practitioners prior to conducting any form of objective examination of the patient.
Add Non-Patient-Identified Problems to the Problem List	The PT documents: existing problems that the patient did not identify, problems that need to be addressed to prevent further disability, and examination findings that are significant to the problem identified.
Generate a Hypothesis as to Why the Problem Exists	The PT provides a rationale for the final diagnostic hypotheses generated. The final physical therapy diagnostic hypothesis is identified for patient-identified problems and non-patient-identified problems. These hypotheses are phrased in pathologies, functional limitations, disabilities, and impairments, and provide a reason for intervention.
Identify the Rationale by arguments or data for Believing Anticipated Problems are Likely to Occur Unless Intervention is Provided	The PT provides a justification for the hypothesis generated and presents arguments based upon data gathered during examination. The therapist provides justification for treating patient-identified and non-patient-identified problems.
Refine Problem List	The PT refines the problem list to only include problems that the physical therapist is able to treat. The therapist gives justification for treating the patient.
Referral if Needed	The PT refers to other providers if the problem is outside of the physical therapist's scope of practice. The PT provides justification of the need for referral. This referral can occur at any step in the decisional process but is most likely to occur as different types of data are collected and analyzed, or at the conclusion of the data collection process.

Sequence of the reasoning process employed pre- and post-application across case. Findings within this section are first relayed by illustrating the process utilized by each subject in Figure 5.1. On the right side of each participant's summative figure is the sequence utilized pre-application use, and on the left side of the figure is each participant's sequence of reasoning used post-application use. In considering these figures, it is important to note three thematic elements related to Finding 3: 1) Participants used more steps to proceed through the reasoning process pre-intervention and less steps post-intervention to proceed through the reasoning process., 2) Participants were less-ordered in their reasoning process pre-intervention, and more-ordered in their reasoning process post intervention, and 3) Participants required more cues for the reasoning process pre-intervention, and less cues to complete the reasoning process post-intervention.

Figure 5.1. Sequences of the Reasoning Process Utilized by Participants.

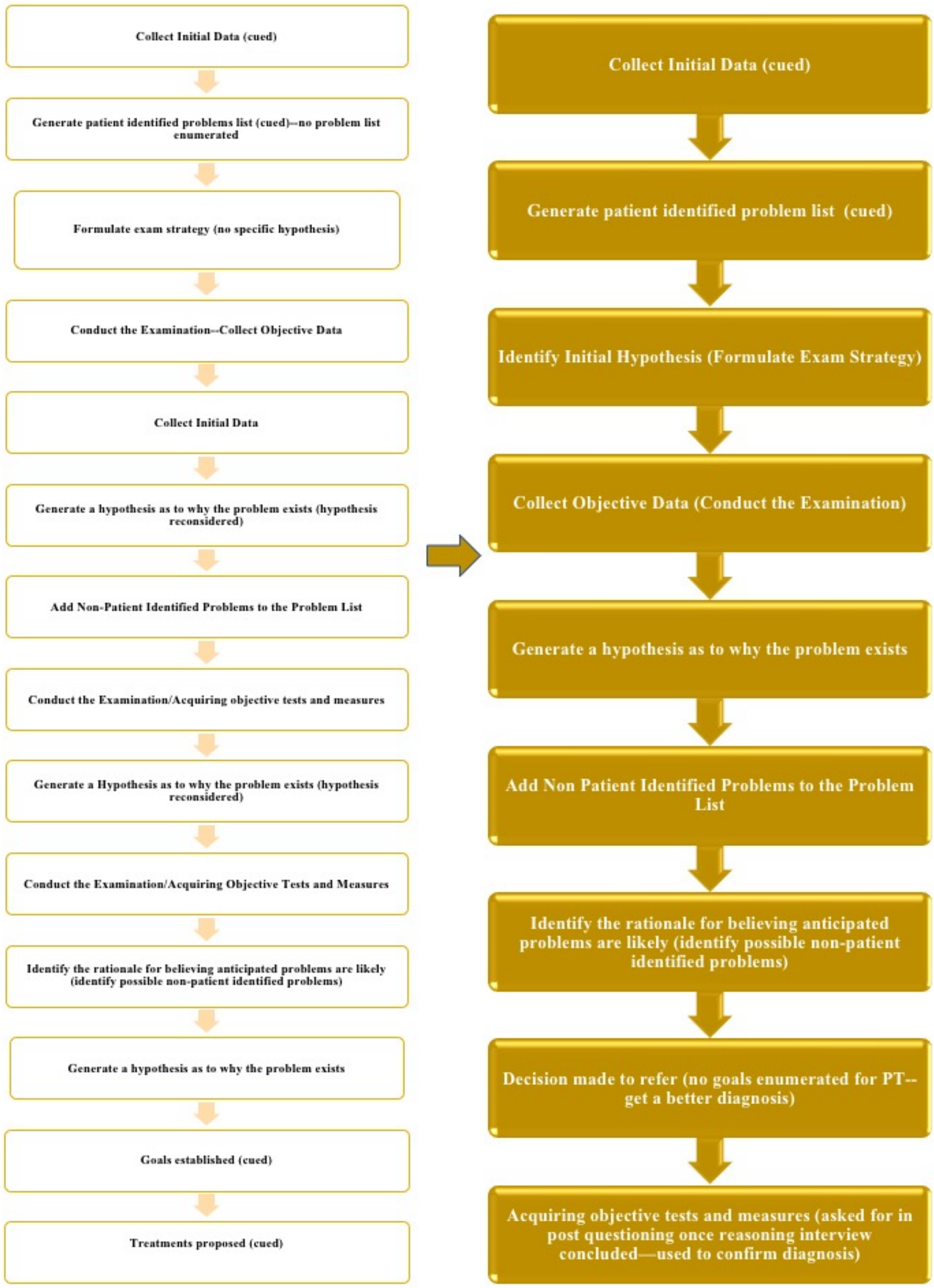
Sara: Clinical Reasoning Order Used Pre Intervention

Sara: Clinical Reasoning Order Used Post Intervention



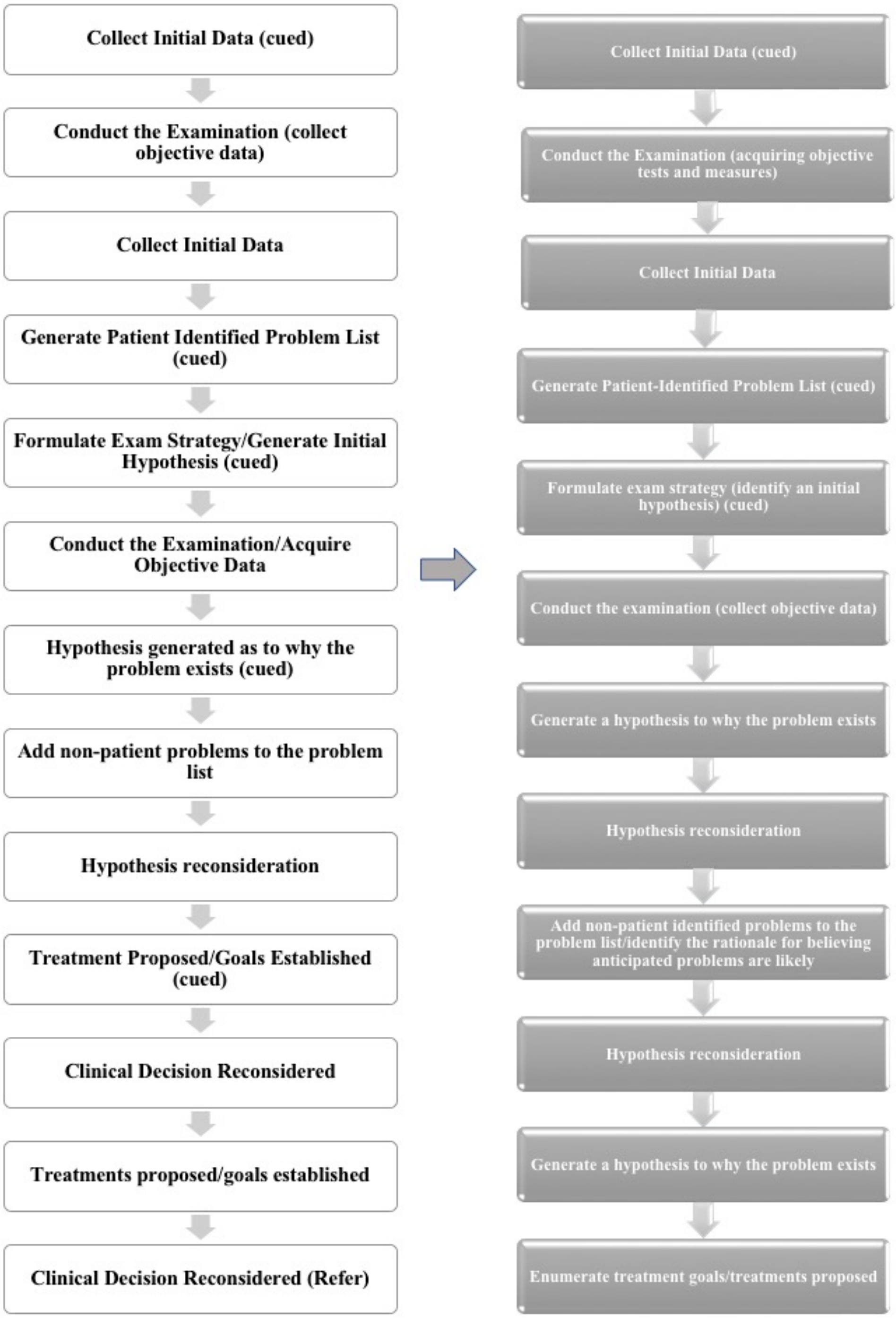
Bryan: Clinical Reasoning Order Used Pre Intervention

Bryan: Clinical Reasoning Order Used Post Intervention



Marcus: Clinical Reasoning Order Used Pre Intervention

Marcus: Clinical Reasoning Order Used Post Intervention

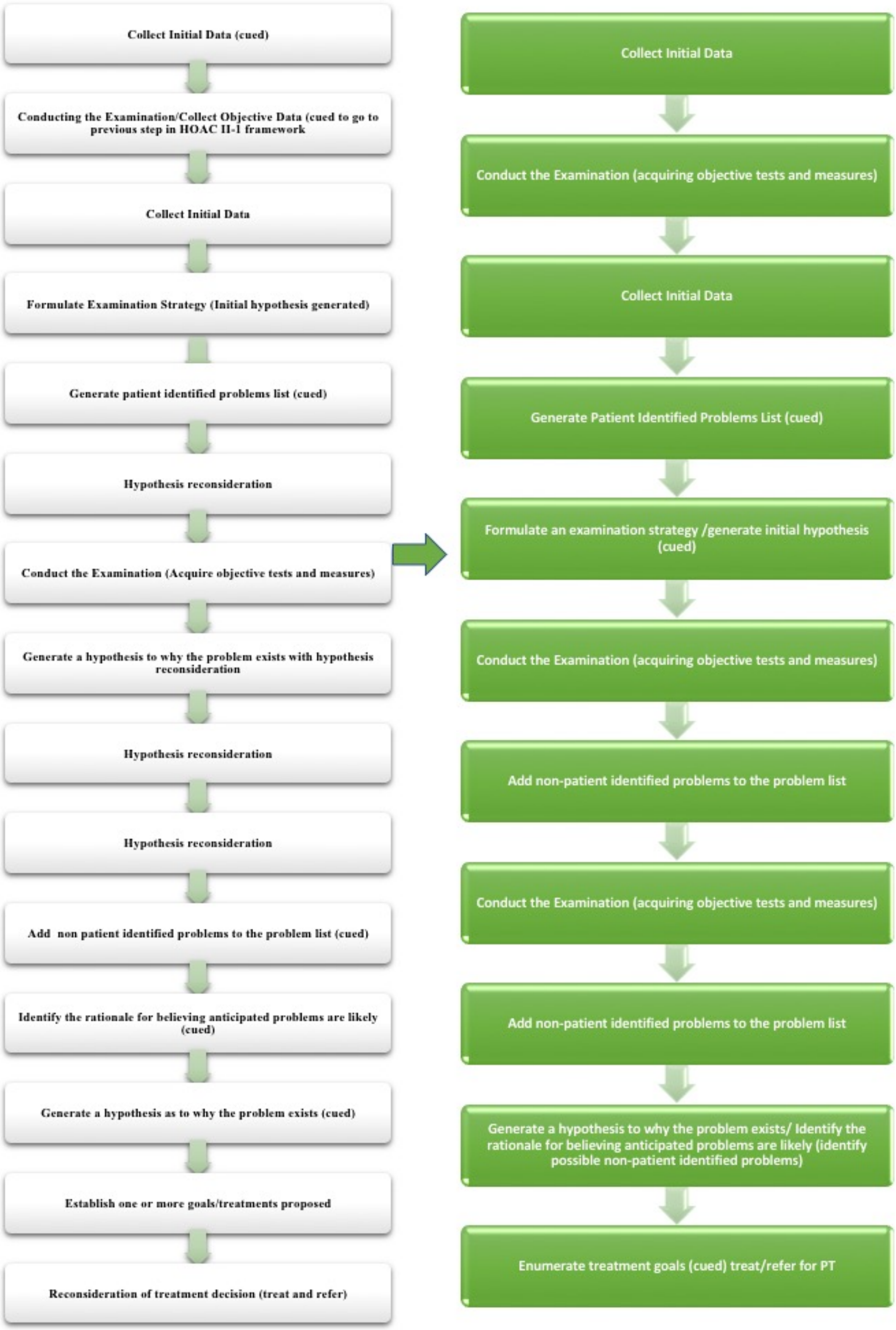


Shannon: Clinical Reasoning Order Used Pre Intervention

Shannon: Clinical Reasoning Order Used Post Intervention

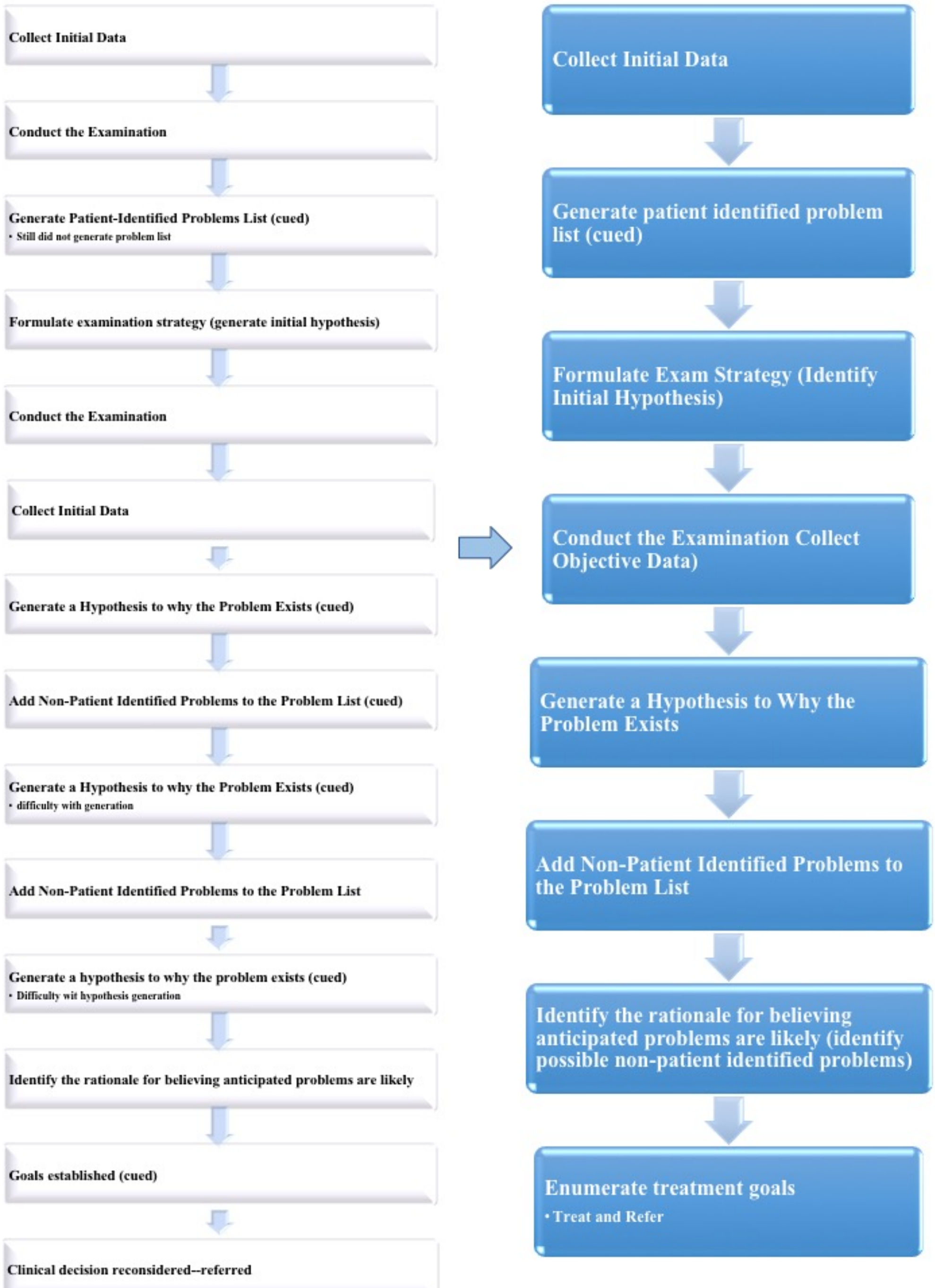
Kerry: Clinical Reasoning Order Used Pre Intervention

Kerry: Clinical Reasoning Order Used Post Intervention



Charlotte: Clinical Reasoning Order Used Pre Intervention

Charlotte: Clinical Reasoning Order Used Post Intervention



Evidence related to this assertion is also noted in Table 5.6., below, which summarizes the information found in the figures, relaying the number of steps taken pre-intervention (unshaded) and post intervention (shaded), the number of cues required to sequence the task, and the number of out of order or skipped events.

Table 5.6. *Pre and Post- Task-Based Interview*: Number of Steps Taken, Number of Cues Received, Number of Out of Sequence or Skipped Events.

Student-Participant	Pre-Inter-vention Number of Steps Taken (9 steps in HOAC)	Pre-Intervention Number of Cues to Complete Sequencing of Task	Pre-Intervention Number of Out of Sequence or Skipped Events	Post-Intervention Number of Steps Taken (9 steps in HOAC)	Post-Intervention Number of Cues to Complete Sequencing of Task	Post-Intervention Number of Out of Sequence or Skipped Events
Sara	14	6	2	9	2	1
Bryan	14	5	6	9	1	3
Marcus	13	7	4	12	3	4
Shannon	14	5	5	10	3	2
Kerry	15	5	7	11	2	4
Charlotte	14	4	8	8	1	2

Exemplars of participant statements used to derive the data above, matched to the step in the framework that they represented are illustrated in Table 5.7., below.

Table 5.7. HOAC II, Part 1 Framework Example Quotations by Participants Pre- and Post-Application Use.

Step in the Framework	Quotations from the Pre-Task Based Interview	Quotations from the Post Task-Based Interview

Table 5.7. (continued).

Collect Initial Data	**Sara: "**I would want to know the type of pain she's experiencing, if it's aching, if it's numbness, sharp, shooting, anything like that. I would want to know the pain levels…how bad is her pain, and then also how long does her pain last, does it go away after she's done walking."	**Bryan:** "I would ask her where specifically her pain is in the lower extremity, whether it's bilateral or limited to one side."
Generate Patient-Identified Problems List	**Bryan:** No problem list generated. **Marcus:** "She has lower back pain, probably from sitting in her chair for multiple hours of the day without plenty of exercise. I asked about her diet, because her diet has led to certain factors that stricken her blood pressure and diabetes that could also lead to factors in her back pain. Her low activity level could also play a factor in that."	**Shannon:** "The blue toes, I would say is probably not enough circulation going down into the feet. Pain. The atrophy of the calves as well as the being hairless, and then just the health complications that the patient is having." **Kerry:** "Her pain, it worsens when it's elevated or if she's doing exercise. There could be a systemic issue."
Formulate Examination Strategy	**Kerry:** "I was thinking Lymphedema…My issue, well my thinking what my diagnosis could be she could just have muscular fatigue."	**Shannon:** "I'm thinking possible arterial insufficiency, is what I'm thinking, initially." **Charlotte:** "some arterial insufficiency"
Conduct the Examination, Analyze Data, Refine Hypotheses, and Carry out Additional Examination Procedures	**Bryan:** "I'd want to take probably range of motion of her hip and knees and then have her do some functional tasks to see what aggravates it and what possibly alleviates the pain."	**Sara:** Example statement: "I would even take some circumferential measurements, especially she's saying it's atrophied but seeing if it's the same on both sides."

Table 5.7. (continued).

Add Non-Patient-Identified Problems to the Problem List	**Bryan:** "Pain in her lower extremities with walking going down to her calf, she doesn't have any issues with range of motion except in her ankles. I'm fairly confident that it's not anything to do with her [00:12:00] lower extremity joints…I believe she's having referred pain." **Marcus:** "Pain walking, obviously. The short amount of distance that she can walk before she feels pain of two minutes. The fact that she's very sedentary and has a receptions' desk and spends most of her time sitting."	**Sara:** "She's got decreased range of motion and dorsiflexion, but that's not that concerning, and her manual muscle test was actually pretty decent as well. So, I'm not thinking that it's a musculoskeletal disorder. Yeah, she's got diminished sensation for touch and deep pressure, and that could be going along with the ... like there could be ischemia related to the nervous system with her being a diabetic."
Generate a Hypothesis as to Why the Problem Exists	**Shannon:** "There may be a tear in her Achilles' tendon." **Kerry:** "She may have some peripheral arterial disease, because of the ABI. It was below 0.8, which is normal so that's why I thought it was that."	**Shannon:** "I: You had said arterial insufficiency earlier. S: Yeah, that's what I'm thinking still." **Kerry:** "Peripheral artery disease" **Charlotte:** "I do think this is arterial insufficiency and that the patient also has some hypertension issues going on, that may need to be looked at to be better controlled."
Identify the Rationale by arguments or data for Believing Anticipated Problems are Likely to Occur Unless Intervention is Provided	**Charlotte:** "Well, pain with walking is going to be an issue as far as it's going to make her less active, which can affect the cardiovascular system, muscle degeneration, all sorts of things with that. Pain is definitely something that has to be addressed in order for her to stay active and healthy."	**Sara:** "Her diabetes, her high blood pressure, her high cholesterol, then her diminished sensation can lead to other problems 'cause then she could have sores or something like that"

Table 5.7. (continued).

Refine Problem List	**Sara (only participant who performed this step):** "I think the biggest thing being her health history. I'm sure she's seeing a physician for these things or has seen somebody at some point for them, so I would recommend her following up to make sure the diabetes is still under control, the hyperlipidemia is under control. I would want to make the doctor aware of the hypertensive reading that I had for her blood pressure. I'm also finding things that I can help her with [like increasing strength and range of motion].	**Sara (only participant who performed this step):** "Because I think there's some things that I can help her with, the biggest thing being the circulation. Obviously, I can't do anything with her meds and things like that, so she needs to see the doctor for those type of things. But I can help with circulation. I can help with the range of motion since she doesn't have that, because in my mind, I'm thinkin' that if she doesn't have that range of motion, then that could lead to other things, like walking and going up and down stairs and things like that could become of an issue. So, I can address some of the musculoskeletal things as well."

Thematic statements regarding the sequence of the reasoning process employed pre-application use. Each participant's reasoning process during the *pre- task-based interview* was frequently out of congruence with the HOAC-II-1 algorithmic framework, which resulted in difficulty in data gathering and generating hypotheses to accurately diagnose the patient problem. For this reason, each participant received multiple cues from the interviewer to reason using a hypothetical deductive process for sense-making, as exemplified by the number of cues provided by the researcher in Table 5.6. Further exemplifying difficulty with the reasoning process is the number of steps taken during the reasoning process when compared to the number of steps in the HOAC algorithm (9), and the number of out of order events, or skipped events in the reasoning process (Table 5.6.).

Thematic statements regarding the sequence of the reasoning process employed pre-application use. Following the four sessions with the mobile application, in each participant's *post think-aloud interview*, a major theme was that there was evidence of a progression in the ability to sequentially order the reasoning process. Evidence of this is noted in the decreased number of steps taken to reason through the clinical process (in every participant), the decreased cues required from the interviewer to complete the reasoning process (in every participant), and the decreased number of out of order or skipped events, (in every participant except Marcus) (Table 5.6.). In Marcus' case, the reason for the maintenance of the number of out of order events was due to multiple instances of hypothesis reconsideration when formulating his final diagnostic hypothesis, due to minimal difficulty integrating data into the final diagnosis, as evidenced by the following statement:

> "Yeah. That's what made me think of that. So, helps me ... Okay, so something that made me think that, but I'm also worried about her decreased muscle strength in her calves. That was the only thing that originally made me think it was a venous ... but a vein issue, [would] be better with the increase in elevation."

This difficulty resulted in two instances of hypothesis reconsideration, and ultimately a correct hypothesis.

Finding 4) There Were Improved Clinical Reasoning Outcomes Related to Making a Diagnosis Post Intervention. This Outcome Resulted from an Increased Ability to Utilize a Higher Order Reasoning Strategy and Improved Sequence of the Reasoning Process. However, Some Errors Persisted Related to Making Treatment Decisions.

Expressed within this section is an examination of the narrative process of reasoning expressed in the *pre-and post-task-based interviews* that provides a corroboration of the sequence (congruence or incongruence with the HOAC-II-1) and types of reasoning employed (Gilliland) pre and post intervention. First, by examining data in this way, a description of how integration between the selection of a reasoning strategy and order of reasoning strategies effects a diagnostic decision may be presented. Secondly, data presented contributes to the elaboration on the changes produced by the mobile application to the relationship between the sequential orientation to the HOAC II-1 to the types of clinical reasoning strategies utilized.

The major theme related to Finding 4, identified within this section, is that when less sophisticated, lower order reasoning strategies were used in combination with a less-organized sequence of reasoning, that diagnostic decisions were negatively affected (present pre-application use). Conversely, when higher order, more sophisticated reasoning strategies were used in combination with a more-organized sequence of reasoning, that diagnostic decisions were more likely to be correct (present post-application use). Another theme emergent from these data was the presence of errors in the reasoning process) both pre (errors in both diagnostic reasoning and in the treatment decision) and post-intervention (errors in the treatment decision). Subsequently presented are data and participant statements from pre-intervention and post intervention to justify these thematic assertions.

Integration between strategy and sequence pre-application use collective case. Prior to using the application, each student-participant was unsophisticated in their reasoning strategies, required multiple cues to complete the reasoning task, and had a number of out of order or out of sequence events. The lack of strategy and use of a disordered reasoning process contributed to several problems related to the articulation between reasoning strategies selected and sequence used by participants. Therefore, errors occurred and participants had difficulties in: the integration of data to successfully make a diagnosis of the patient problem, considering patient identified problems in an integrative manner, formulating a treatment strategy, and identifying goals. This is best exemplified in the fact that, prior to using the mobile application, no student-participant achieved a correct initial hypothesis (a diagnostic error) or treatment decision. Further, every participant, except for Kerry, did not make a correct final diagnosis. Kerry's correct diagnosis of arterial insufficiency was due to her use of a rule in rule out strategy in which she was able to switch her primary hypothesis and test others during the reasoning process. In order to further illustrate difficulties found in student-participants, which led to errors in both diagnostic reasoning and decision making towards appropriate treatment, four problems that interfered with the reasoning process will be presented in a collective case format, using quotations from various participants.

The first problem noted in the overall process related the lack of focus of the subjective questions when analyzed in relationship to the patient's stated problem in all participants. Two examples will be provided from Sara and Charlotte, respectively. First, when Sara was working through the collection of initial data, Sara spent three minutes collecting data related to the patient problem, and only asked general questions related to pain, health history, and previous injury. This is relayed by the following statement:

> "S: I would want to know the type of pain she's experiencing, if it's aching, if it's numbness, sharp, shooting, anything like that. I would want to know the pain levels on a scale of zero to 10, how bad is her pain, and then also how long does her pain last, so does it go away after she's done walking or does it persist. I want to know her previous health history, so if she has any underlying factors that could be causing this. Another thing that I would be interested in is…any previous injury that she might've had to that lower extremity as well."

After receiving the answers to these questions, she did not follow up to receive more information from the patient to further elicit information that could help direct the evaluation process.

A second example provided is elicited from Charlotte's narrative. Charlotte spent three minutes collecting data, and only asked general questions of the patient as exemplified by the following statement:

> "I would want to think about ... I would want to get the information from the patient about where the pain is and what type of pain it was, have them describe the type of pain, as well as how extreme the pain is at different times, particularly when walking long distances, and what other activities the pain has been limiting them from doing. I would also ask about some patient history as far as medications, prior medical issues, any current comorbidities that are going on, as well as previous injuries."

In congruence with Sara, Charlotte did not ask any follow up questions to help gain more specific subjective data that could help guide the reasoning process.

A second issue during the process related to each student-participant's limited linkage of the subjective data to the articulation of the initial hypothesis and the patient identified problem list, therefore creating difficulties with identifying a correct hypothesis and creating errors that persisted throughout the reasoning process. During the problem identification step, student-participants either did not identify a problem list (Bryan), or considered limited information in their identification of patient identified problems. Further, even though participants identified co-morbidities that the patient had as risk factors for future/anticipated problems, they did not always integrate these data into the problem-solving process. For example, Sara only identified and considered one problem in her *generating a patient-identified problem list* step (the activity limitation) by stating, "the biggest thing is her restriction of activity because she can only walk 100 feet before having pain, and it becomes an eight out of 10, so that's a huge limitation for her." Within this step, she did not consider the types of pain the patient experienced, or the patient health history in formulating her problem list, leading to difficulties in articulating a correct hypothesis. Thus, she subsequently identified a blood clot as her initial hypothesis, which did not relate to the patient identified symptoms of:

> "I: Her pain is relieved by rest, and the pain worsens with exercise. She describes the pain as cramping and aching. Her pain, she rates it at eight out of 10 with activity, a zero out of 10 with rest. The pain is in both calves. She's able to walk two minutes until the onset of pain, which is about 100 feet. The pain resolves after five minutes of rest. She can't remember any injury."

Another example of this limited consideration was evident in Marcus, when the patient did not describe low back pain, however, Marcus, in his problem statement related:

> "She has lower back pain, probably from sitting in her chair for multiple hours of the day without plenty of exercise. I asked about her diet, because her diet has led to certain factors that stricken her blood pressure and diabetes that could also lead to factors in her back pain. Her low activity level could also play a factor in that."

This error in his problem statement persisted as he continued to perform his exam and led to him identifying an incorrect and non-specific final hypothesis.

The third problem in the reasoning process was the lack of relationship of the tests selected in the objective examination to the initial: data collected, problems identified, and hypotheses generated, resulting in difficulty with integration of data to formulate a diagnosis, and diagnostic errors. This can be best exemplified by Sara's selection of non-specific and non-confirmatory tests for her hypothesis of a blood clot such as: blood pressure, orthopedic special tests, range of motion in the knee, ankle and hip manual muscle testing, palpation, Homan's sign, and visual observation. After receiving results of these tests, Sara proposed a non-specific diagnosis, stating:

> "All of the orthopedic tests came back negative, so I'm thinking this is more of like a vascular issue because, especially with the paleness of the skin and the blue toes, it basically means she's not really getting circulation that she needs there, and then with the blood pressure being high, I'm thinking this isn't a muscular or a ligamentous issue or something like that. It's going to be more vascular."

When asked to be more specific about her final diagnosis, she identified her diagnosis (blood clot) without having substantiated data to support her conclusion. Later Sara expressed, "My diagnosis, I'm still not sure what it is."

Another example of this problem is found in Shannon, where she only asked for range of motion, manual muscle tests, and then had difficulty formulating a diagnosis from the selected tests as evidenced by her statement, "my main hypothesis is I'm thinking it's maybe something to do with ... I don't know." She did not select further testing, and then when asked for a final hypothesis, she stated "I don't know if I remember the body or not, there may be a tear in her Achilles tendon."

Fourth, and finally, all participants demonstrated difficulty in formulating a treatment decision, or recommending an appropriate treatment (a graded exercise program). This difficulty may have been due to all participants except for Sara skipping the refine problem list step, or due to the diagnostic errors present. This is exemplified by Charlotte, who stated, "I don't have a real diagnosis for her… I don't have a clear diagnosis…I don't know if [providing treatment] would be the best case. I want to [refer] to work towards finding out what's causing it." Congruence with this statement is expressed by Sara when she stated,

> “I would want to refer for that purpose and see what's going on there, especially since she has the history of the heart attack, the diabetes, and the hyperlipidemia, and then I'm getting a high blood pressure reading on her. In the meantime, I would say, "I think this is very serious. You need to go see your physician, but here's a few exercises that I would like you to start doing."

However, when asked why she made this decision she stated, “I mean, if they're ... I guess this is just a question. If they're coming to see us, aren't we supposed to treat them?” When further probed, Sara decided to refer to the physician, and did not articulate goals, due to uncertainty about the diagnosis.

Integration between strategy and sequence post-application use collective case. Following experience with the mobile application, all student participants achieved the ability to use higher order reasoning strategies, utilized less cues to complete the reasoning process, and most had fewer skipped or out of order steps. Because of these changes, all participants were able to achieve a correct initial and final hypothesis for the patient problem (arterial insufficiency), which indicates an improvement in the ability to make a diagnostic decision. Further exemplifying improvement post intervention is a more-refined relationship between strategy and sequence. This improvement is evidenced by the presence of: more focused subjective questioning, more time spent in the collection of initial data, and a better relationship among: patient identified problems, subjective information collected, initial problems and hypothesis identified, objective tests selected, problem reconsideration, and final hypothesis generation. In spite of these improvements, every student-participant had difficulty with formulating a correct treatment strategy, as all student-participants made errors in their treatment decisions. Data to support these assertions will be subsequently presented using examples from different student participants' cases.

First, within each participant's reasoning process, on the whole, there was more time spent in the collection of initial (subjective) data and increased focus in questions selected to identify the patient problem. An example of this process is found in Sara's narrative. Within the step of *collecting initial information*, Sara spent increased time collecting data (8 minutes) from the interviewer to gain a more detailed subjective description from the patient. Further evident in her collection of data was the process utilized, moving from less specific questioning, to more specific questioning, keeping the patient problems in mind. In her initial questioning, Sara once again asked general questions such as the presence of previous injury, location and type of pain, pain intensity, and aggravating and alleviating factors for pain. In contrast to the initial exam, however, Sara also asked for medications the patient was on to correlate for comorbidities, for any systemic symptoms such as dizziness the patient was having, and for co-morbid medical conditions. Her rationale for asking these questions is summarized when she stated, "Then with this being insidious onset, you want to think about what else she might be having going on in her medical history that could pertain to this issue." After receiving these answers, she asked for any changes the patient had noticed regarding the condition of her legs, consultations with physicians, and for imaging studies done in order to "give [me] a better idea of what might be precipitating the cause." Evidence for this better focus in data collection is also found in Charlotte's narrative, where she spent three minutes longer in the collection of initial data, and when she stated:

> "Thinking with the questions that ... general questions that we need to ask during an evaluation. Then, also specifically, looking at her symptoms, as far as lower extremity

> pain. The fact that it's bilateral made me think that it was something in the circulatory system, so I wanted to ask questions that targeted that issue, which she does have a history of, and just to get a background on patient history and what medications she's taking."

Finally, evidence for this better articulation of the questions asked to the initial case presentation was present in Marcus' narrative when he discussed his rationale for asking for the initial data that he requested. Marcus stated:

> "I want to know her medication and family history, considering her age. Around 60, people are usually on a couple medications. I want to see what kind she had. I asked about how far she can walk since she said her ability to walk and go shopping at Walmart was affected."

Secondly, improvements in student participants' ability to identify relationships between: patient identified problems, subjective information collected, initial problems and hypothesis identified, objective tests selected, problem reconsideration, and final hypothesis generation, is illustrated subsequently. An example is found in Bryan's narrative, when he identified a problem list. Bryan stated:

> "That she has pain in both her calves, has difficulty ambulating for long periods of time, she has pain when her legs are elevated and does better when they're in a dependent position…she obviously, has a couple of comorbidities we have to keep in mind."

After identifying this problem statement, he was able to use this problem statement to define his initial hypothesis of DVT or vascular insufficiency. Using this information, he selected more specific tests to test his hypothesis, non-specific tests, and tests to address comorbidities, by selecting vital signs, pulse comparison between extremities, an ankle brachial index, sensation, ROM, and a Trendelenberg test. When asked for a rationale for the selection of these tests, Bryan stated:

> "Because of my initial hypothesis, I wanted to test out her vasculature. Vital signs good to know. Then I wanted to test out for arterial insufficiency and anything else that could point towards vascular problems."

After making this statement, he stated that the patient had arterial insufficiency, with a rationale of:

> "With the ABI result and then knowing that her pain comes on when her legs are elevated, so when gravity isn't helping her vasculature out. Then the diminished sensation and the diminished pulse kind of help with that as well."

In spite of this better diagnostic process, Bryan did not define which problems were appropriate for a physical therapist to treat, leading to a treatment decision that was not best-evidenced (to refer).

Further evidence is noted for this improvement in the relationship between patient identified problems, subjective information collected, initial problems and hypothesis identified, objective tests selected, problem reconsideration, and final hypothesis generation is found in Sara's narrative. As she transitioned from collecting her initial data, Sara was first able to use the answers to the subjective questioning to identify a problem list: stating, "the cramping and aching of the calf, all of her comorbidities, previous history of a heart attack, and then her integumentary issues as well…and the muscle atrophy." Second, she was able to perform integration of the subjective information into her hypothesis generation process by stating,

> "One thing that I'm thinking is there could be something with the arterial system, especially being high cholesterol, high blood pressure, and diabetic, that's gonna put more

> strain on the arterial system…. but the fact that being in a dependent position makes it feel better, in my mind, that makes me think that it's not a venous issue. But I'm not sure if that's correct. But in my mindset, if you're in a dependent position, your veins should be okay if it feels okay to be in that position, if that makes sense…. Then worse with exercise makes me think that you're having to pump more out so that increases the blood pressure, so that's gonna put more strain on the arterial system. hen also, the cyanosis of the toes means she's not getting the blood flow down there. So that could mean that the arterial system just isn't getting where it needs to be to give you that oxygen and blood."

Based upon this reasoning process of identifying a hypothesis and some patient problems, Sara articulated objective measures that addressed three areas: comorbidities, non-specific information, and hypothesis specific information. First, she addressed the contribution of comorbidities to patient problems by asking for objective measures of: vital signs, checking for sensation and edema, and heart auscultation. Secondly, she requested to check non-specific information such as range of motion and strength testing. Finally, based upon the possibility of an arterial issue she selected to perform an ABI. Her rationale for selecting this focus for the tests selected included the following two statements, "I would want to do sensory testing, especially with diabetes." And "Because I was leaning towards something wrong with the vascular system given her medical history and what makes it better and what makes it worse and the type of pain." Next Sara utilized data (ABI) from the objective measures to identify her final hypothesis of arterial insufficiency, stating that the test confirmed "That she's getting decreased blood flow to the lower extremity." Later she also demonstrated integration of all data collected during the interview process when she presented her rationale, stating, "cause in the subjective, she talked about the dependent position being better…Then taking her comorbidities into a factor, what are they likely to cause? So, she could be having atherosclerosis and things like that that could then lead to the decreased oxygenation and blood flow through the arterial system."

After identifying this as her patient diagnosis, Sara demonstrated better ability to identify and incorporate patient-identified and non-patient-identified problems into her problem list, stating

"her artery isn't working, her sensation, yeah, she's got diminished sensation...like there could be ischemia related to the nervous system with her being a diabetic, her dorsiflexion, she doesn't have any so that could present problems with walking."

Finally, evidence is provided for improved articulation of tests to hypotheses in Kerry's narrative, where she identified an initial hypothesis of arterial or venous insufficiency. In discussing her rationale for selecting the tests that she requested, she stated, "They would help me rule out some of my initial hypotheses." Finally, when she incorporated her non-patient identified her problem list and her patient identified problem list in giving a rationale for her final hypothesis of peripheral artery disease, she stated: "[The] ABI indicated that. Again, when she exercises and she's not getting enough blood flow to her tissues, and in case there could be something going on with the arterial system."

Persistence of errors in the reasoning process related to the treatment decision. In spite of the improvements noted above, all participants continued to have difficulty with generation of a treatment decision and in articulating goals for treatment. Errors were made amongst all participants, when deciding to refer or to treat using strategies that were not the best evidenced according to the expert recommended treatment plan---a graded exercise program. When asked, one participant, Sara, alluded to having difficulty with making the decision to treat or refer and formulating goals, relating it to a lack of knowledge, stating, “Well, I'm not really sure really what I would do for someone who has arterial insufficiency or what our guidelines are for that, but I'd probably send her back to the doctor, and “I can’t remember [what to do].” Evidence for this difficulty is also found in Marcus’ narrative, when he states: “I would be all right with just saying to refer or to treat [the] patient, but I'm not sure [what to do].” Finally, evidence for difficulty in the making a treatment decision is also found in Shannon’s narrative when she stated: “Yeah, [I want] to refer…. I don’t know, I guess to confirm the diagnosis.”

Finding 5) Participants’ Perceptions of Influential Constructs that Facilitate Clinical Reasoning Either Remained Constant or Changed.

Outlined within this section is Finding 5 which relates to perceived influences on clinical reasoning outlined by the student participants both pre-and post-application use, which either remained constant or changed. The themes related to this finding were derived by an inductive coding process, where codes were developed, collapsed in to axial codes and then merged into themes (Saldaña, 2015), with the assistance of Atlas TI. For themes identified with in this section, both major and minor themes have been identified. A theme was considered to be major if 3 or more participants expressed statements that were congruent with the theme, and minor if less than 3 participants expressed statements that were congruent.

Perceived influences on clinical reasoning pre and post-application use collective case. In student-participants’ initial and final reflection upon the case, and upon experiences that could influence clinical reasoning, several themes emerged that were consistent amongst all participants. Other themes that emerged were evident within some, but not all participants. This resulted in five major themes and one minor theme emerging pre-application use, and six major themes and two minor themes emerging post-application use. These themes are presented in Table 5.8 with the numbers of participants identifying with the theme pre and post.

Table 5.8. Perceived Influences on Clinical Reasoning Pre- and Post-Application Use.

Theme	Number of Participants Identifying with Theme Pre-Intervention	Number of Participants Identifying with Theme Post-Intervention
There is a need to collect more information to support clinical reasoning.	4	0
Collecting appropriate tests and measures supports the clinical reasoning process.	0	6
Knowledge is impactful for supporting the clinical reasoning process.	5	6
Previous experience is impactful for supporting the clinical reasoning process.	6	5
Process management is needed for clinical reasoning.	3	1
External factors like scope of practice, and PT role definition are involved in clinical reasoning.	4	5
Confidence is needed to support clinical reasoning.	2	3
Sense making is necessary for clinical reasoning	0	3
Articulation and reflection are necessary for clinical reasoning.	0	1

Exemplars of supporting statements for emerging clinical reasoning themes pre-application use. Relayed subsequently are the themes that emerged pre-application use with selected statements from the student-participants that support each theme, starting with major themes, and concluding with minor themes.

Major themes identified. There were five major themes that emerged regarding supportive factors for clinical reasoning prior to utilizing the mobile application under study. These were:

1. Previous experience is impactful for supporting the clinical reasoning process.
2. Knowledge is impactful for supporting the clinical reasoning process.
3. There is a need to collect more information to support the clinical reasoning process.
4. Process management is needed for clinical reasoning.
5. External factors like scope of practice, and PT role definition are involved in clinical reasoning.

Each of these themes will be presented subsequently with selected supporting statements from student participants.

Prior to using the application, participant statements supported an emergent theme that previous experience is impactful for supporting the clinical reasoning process. An example of a statement that exemplifies this theme is found in Kerry's narrative when she imparted:

> "Previous experience. Thinking about my family, I have an aunt who was in her 60s, and she's not sedentary, well she is sedentary, but best that's probably what I thought about it. I thought the older population as a whole in general, as far as some of the public health general parameters about them."

Shannon also exemplifies this theme when she states:

"Personal experience…. How does it influence? I guess pulling information from things that I know have been beneficial either to myself or other people that I've known that may have had similar problems."

Another major theme that emerged in participants' statements was the theme that knowledge is impactful for supporting the clinical reasoning process, which is supported by Shannon who conveyed:

"I guess just from lectures that I've had, they've given a guide of questions that you would need to ask in order to come up with the diagnosis or things that you would need to know."

This construct is additionally expressed by Marcus when he states:

"especially with the conditions, with physical agents I'm going through contraindications and all that, being able to decide with possible test results or history of conditions whether or not it's appropriate to continue on with the patient."

There is a need to collect more information to support the clinical reasoning process was another theme that was emergent from the data. This theme is supported by Kerry when she stated, "Maybe asking more questions, more patient interview and questions, and by Shannon, when she said, "I think probably with the tests that I did, I'm not, just because I'm not for sure that I've done, I don't know, maybe not doing enough to confirm what I'm thinking."

External factors like scope of practice and PT role definition are involved in clinical reasoning also emerged as a theme. This theme is supported in an example statement by Charlotte who expressed:

> "Every time I would think of something that could be going on with the patient, I thought of, "Well, what does that mean as far as, does this need to be evaluated by a doctor, or is it something I can treat? Is it something I can work around?"

This theme is also supported by Bryan when he discusses what he considers when deciding to treat or not to treat a patient. He stated, "the scope of practice and what lies in that, what lies out of that, when it's a good idea to get a second opinion on something or to continue with treatment."

Of the remaining major theme, participants expressed that process management support (related to the order of the process or managing data) is needed for clinical reasoning, which is supported by an example statement from Shannon who cited: "For me, I guess going in order…. Like an ordered process." Further providing support for this theme is Bryan when he stated, "[I need to] just keep everything in mind, and not get too focused on one thing at a time."

Minor theme identified. Considering the final theme that emerged from patient data, confidence is needed to support clinical reasoning, Kerry best supports this statement when she stated:

> "Specifically, I just want to be more confident in myself to know that I'm providing the patient with the accurate amount of care, because they're not going to ask me why, they're just going to do as I say. So, I want to be confident in myself to make sure that I'm providing the appropriate treatment for them, depending on their situation."

Further providing support for this theme is Shannon, when she stated, "I know for sure just me being confident."

Exemplars of supporting statements for emerging clinical reasoning themes post-application use. After utilizing the application, student-participants were once again asked to reflect upon the case used in the *post-task-based interview* and on experiences that could influence clinical reasoning. Described subsequently will be the major and minor themes identified with supporting statements to support the emergence of these themes.

Major themes identified post-intervention: There were six major themes identified post intervention. These were:

1. Knowledge is impactful for supporting the clinical reasoning process.
2. Collecting appropriate tests and measures supports the clinical reasoning process.
3. Previous experience is impactful for supporting the clinical reasoning process.
4. External factors like scope of practice, and PT role definition are involved in clinical reasoning.
5. Confidence is needed for clinical reasoning.
6. Sense making is necessary for clinical reasoning.

These themes will be subsequently presented with their supporting statements.

Post application use there were two themes identified by all participants. The first theme identified was that knowledge is impactful for the clinical reasoning process, which is supported by Sara when she stated, “[I need to] Learn more about the vascular system…. Cause especially with direct access and people with so many comorbidities knowing what I can and can't do.” Further support for this theme is provided by Bryan when he cited**,** “Then learning some of those tests that you would do to help confirm or rule out different diagnoses.”

The second theme identified by all participants was that collecting appropriate tests and measures supports the clinical reasoning process. This represents a change from the previous theme, there is a need to collect more information to support the clinical reasoning process, in that participants referenced not just the need for more information, but more specificity in information needed to firmly establish a diagnosis in accordance with their diagnostic hypothesis. This theme is especially supported by Bryan when he imparted:

> "and then appropriate tests, and interventions to ... Or the physical exam aspect, collecting the data while keeping in mind, like I said, the past history and any relevant surgeries or anything like that." "The relevancy of past history comorbidities and all that playing into what tests you can do with them and how it plays into the diagnosis."

Further supporting this statement is Sara who imparts:

> "I think that also getting more specific [in data collection] for the lower extremity 'cause I didn't ask about the pulse rate and everything for the lower extremity and checking dorsal pedal pulse. I just asked heart rate, which is only regular pulse, which could be different. So I have to keep that in mind."

Two other themes were identified by 5/6 participants. The first theme, external factors like scope of practice and role definition are involved in clinical reasoning was identified in every participant except for Marcus. This theme was exemplified by Sara when she stated:

> "Because there are things on here that are within my scope of practice, like treating the musculoskeletal, and helping with the circulation, and patient education. But at the same time, as far as if the meds need to be adjusted or if there's something more going on with her heart, like maybe she needs some other imaging done on it to make sure there's nothing goin' on up in there since she does have a history of a heart attack, I can't do that."

Kerry also supports this theme when she states,

> “As far as the pathophysiology of the condition, if it is completely out of my scope or something that I personally cannot control. If the patient were to have an occlusion, I can't treat her until that's fixed. If there was an issue that needs to be recognized by a physician, or the patient needs to undergo surgery to remove an obstruction or some kind of issue that they have, so that we could continue with therapy.”

A second theme, previous/clinic experience is impactful for supporting the clinical reasoning process was identified by every participant except for Kerry. Marcus relays support for this theme when he stated:

> “I know with [my] experience you pretty much ... They always came with the one, like when we talked about treating patients, they had already been to a doctor, a doctor already diagnosed, and they pretty much told you what you want, or that they needed you to do with the patient. So, we never really talked about do we treat this patient versus not treating this patient. They always came.”

Congruently, Charlotte also expresses:

> “Still working experience, everything that I've seen, and also observation hours, just watching the process, having PTs go through that process [has influenced my clinical reasoning].”

Further, half of the participants (Marcus, Shannon, and Charlotte) identified two themes: that confidence is needed for clinical reasoning and that sense making (related to knowledge support and knowledge of scientific practices) is necessary to support clinical reasoning. The first theme, that confidence is needed for clinical reasoning that was best exemplified by Charlotte when she imparted:

> “I'm definitely influenced by my confidence that we can treat without needing referrals for most, actually, most things that we'll end up seeing and knowing those clear signs where it's dangerous to treat, or definitely need a referral to assist treatment or work on some other aspect of it.”

Other support for this theme is provided by Marcus when he stated:

> “Because, if I knew for a fact that I was coming to one decision, I would be all right with just saying to refer or to treat patient, but since I'm not sure about what, it's making me question the other…But I do feel more confident than last time.”

Secondly, the theme that sense making (related to knowledge support and knowledge of scientific practices) is necessary to support clinical reasoning, is represented by Marcus' statement:

> “That way you have the best opportunity to like, a lot of times you tell you use this in a situations, but the literature also supports it. So, it helps me get not only that the literature supports it, but it's also plenty of evidence and personal experiences that says help.”

Charlotte also supports this theme when she references the need for expert support for knowledge provided instructors when going through case scenarios in class when she states:

> “Having going through those processes and then getting feedback from her on areas that we ... that I've missed or could have explored further, or things like that, that process has been helpful. Then, same with physical agents, same kind of situation with case scenarios, talking through them, realizing areas that I've missed or even done well and been able to bank that information for later.”

Minor themes emerging post-intervention. Two minor themes emerged post intervention from participant statements, namely that: 1) articulation and reflection is necessary for clinical reasoning, and 2) process management is necessary for clinical reasoning. Supporting statements that lend evidence to these themes will be presented subsequently.

First, in the case of the emergent theme that articulation and reflection is necessary for clinical reasoning, support is provided by Charlotte, who expressed:

> "Okay, kind of the same thing I was saying, just being able to look at the symptoms and critically analyze the information in order to come up with a proper treatment. I feel like there's a little bit of delay in that process for me.
>
> Interviewer: Kind of that synthesis and pulling everything together?
>
> C: Exactly."

A second minor theme emerged from Kerry's statement, who identified that process management is necessary for clinical reasoning. This construct was alluded to in the following exchange: Kerry**:** "I can say I learn more linear in doing things orderly. Interviewer: It's kind of having a sequence or a system helps you? K: Yes."

Summary of themes related to participants' perceptions of influential constructs that facilitate clinical reasoning and how they either remained constant or changed. From the pre-intervention interview to the post-intervention interview, there was one congruent theme identified in all student-participants, that knowledge is impactful for the clinical reasoning process. However, most themes that emerged from pre-to post- changed either in their construct, the number of student-participants identifying with the theme, or in identifying different factors that support clinical reasoning. These changes will be relayed subsequently.

In considering how major themes changed in their constructs, one theme (needing more information to support clinical reasoning (identified in Sara, Bryan, Shannon, and Charlotte pre-intervention)) changed in its construct in two ways. First, the theme changed in its thematic statement post-intervention to collecting appropriate tests and measures supports the clinical reasoning process. The change in this construct is due to references made by participants to not just obtain “more information,” but to collect data that was more specific to their diagnostic hypothesis which assisted in hypothesis confirmation. A second change in this construct is the endorsement of the statement by all student-participants.

A second change from pre- to post-intervention was related to the number of student-participants who identified with four of the themes, however these themes were still identified to be major themes. The themes were: Previous/clinic experience is impactful for the clinical reasoning process (changed from all student-participants to all student-participants, except Kerry), confidence is needed to support clinical reasoning (changed from Shannon and Kerry, to Shannon, Marcus, and Charlotte, and therefore becoming a major theme), external factors like scope of practice and PT role definition are involved in clinical reasoning (identified by Bryan, Shannon, Charlotte, and Marcus and changed to all student-participants except Marcus), and process management support (related to cognitive load management or keeping the process in mind) is needed for clinical reasoning (identified by Bryan, Shannon, and Marcus, changed to only Kerry, and therefore reducing in its construct to a minor theme).

Finally, from pre- to post- two new themes emerged. These themes were not endorsed by all student-participants. The first theme to emerge was a minor theme from Charlotte who identified that articulation and reflection is necessary for clinical reasoning. The second and final new theme, sense making (related to discipline-specific expert knowledge and knowledge of scientific practices) is necessary to support clinical reasoning, emerged as a major theme post-intervention, and was identified by Marcus, Kerry and Charlotte.

Post-Only Finding: Perceived Influences of the Mobile Application on Clinical Reasoning

The following section first relays the data analysis process used to identify the thematic statements related to the post-only findings. Next presented are the findings related to individuals' perceptions of the mobile application on the clinical reasoning process.

Data Analyzed

During the post interview, feedback about the mobile application was sought to determine its possible impact on the clinical reasoning process and to determine what changes, if any, needed to be made. These themes were derived by an inductive coding process, where codes were developed, collapsed in to axial codes and then merged into themes (Saldaña, 2015), with the assistance of Atlas TI. For themes identified with in this section, both major and minor themes emerged, using a collective case approach. A theme was considered to be major if 3 or more participants expressed statements that were congruent with the theme, and minor if less than 3 participants expressed statements that were congruent with the theme.

Themes Emerging from Participant Statements

There were three major themes and one minor theme that emerged from data analysis. These are presented subsequently with supporting statements.

Major themes emerging. There were three major themes that emerged related to the impact of the mobile application. These are:

1. The mobile application was impactful in three ways: structuring the process of examination related to process management and sense making related to the disciplinary strategy for problem solving, supporting gains in increased knowledge, and supporting increasing the ability to focus on and identify the problem.

2. The mobile application supported articulation and reflection.
3. The mobile application needs changes.

Theme 1. Collectively, student-participants identified that the mobile application was impactful in three ways: structuring the process of examination related to process management and sense making related to the disciplinary strategy for problem solving, supporting gains in increased knowledge, and supporting increasing the ability to focus on and identify the problem. Statements that support the first part of this theme, that it structured the process of examination were expressed by Sara when she stated:

> "I tried to think in the line of here was your questions that you asked…not just special tests, but vital signs and things like that, that's what reminded me at the end like, "Oh, crap. I didn't think of the lower extremity as a segment. I was just looking at the body as a whole. That's what reminded me of that. I was like, "Oh, oops." …I think it [the mobile application] changed the questions that I asked and the objective information that I gathered. I: Okay. So, more kind of structured your diagnostic process. S: mmm-hmmm [affirmative]."

Further expressing this part of the thematic statement is Bryan when he stated:

> "It [the mobile application] helped to keep me on track while you're coming up with your tests that you want to perform, it constantly asks you if there's any other symptoms or problems you want to identify…it'll kind of give you a couple different choices that you can choose from for the diagnosis. For someone that maybe isn't as confident right away, [they] can feel better about having that list…It keeps you coming back to the beginning of keeping everything in mind. Interviewer: It kind of helps you keep all that initial

information and helps you cluster it? B: Yeah, it brings it to the forefront of your mind so that you don't forget about it while you're running through other things."

In considering the second part of the thematic statement, that the application supports increased gains in knowledge, selected statements from Shannon and Kerry support this emerging theme. Shannon stated: "[The application] introduced me to, I guess, different conditions as well as like tests to confirm or rule out what they are." Further supporting this part of the theme is Kerry's statement that follows:

"The About Condition tab really helped because I think some of it would say expert preferential. If [an] expert would have a preference of treating or not treating with a reason behind it, that definitely influences my thinking if I'm going to treat or not to treat. The expert says, they would normally treat or they wouldn't treat."

Finally, considering the third part of the thematic statement, that the app increases the ability to focus on the problem is especially supported by two statements. First, Marcus relays:

"It helped me think about, since I had to ask them what were some of their symptoms, and what did I think was important, it made me think about go by, "Well, what did they say to me, and what did I find important?"

Further support is provided by Charlotte when she stated:

"[The mobile application] helped me think about focusing tests and procedures on my hypothesis specifically, and that way, I can rule out as I go along versus doing every tests to find out what's going on. I can narrow it down by doing waves of testing."

Theme 2. A second theme collectively identified (by Marcus, Shannon, and Bryan) was that the mobile application supported articulation and reflection. Evidence is provided by Marcus when he stated, "So, it helps me get my thoughts together. But it also made me think of different factors," Shannon when she stated, "It gives me an opportunity to fill in my thoughts, "and finally, Bryan when the following interchange occurred:

> Bryan: "Basically, every tab asks are there any other symptoms? Are there any other notes or problems that you want to address about the patient?
>
> Interviewer: To kind of help you manage your thought process?
>
> B: Right, yeah. If you're not quite sure where you want to put something, then you can put it in one of those extra places…. It made me think more about what I was seeing and what I actually think about the patient's diagnosis."

Theme 3. The final major theme identified was that the mobile application needs changes (n=4), however, these recommendations varied amongst student-participants, and related to changing how problems were identified, having the application automatically save data, increasing the number of cases in the application for more practice opportunities, to correct errors in the debriefing screen (did not always function properly), and to improve support for prescribing treatment. Supporting statements for this assertion are given by Charlotte when she stated, **"**The debriefing screen did not work. It had a glitch…. just it can be improved on and probably will be, is just adding more cases, more information, just as much as possible," and Kerry when she stated "What if you included some modalities? The app could use [more] as far as like treatment." Further evidence is also presented by Bryan, when he stated,

> "I would say the only thing was the scrolling for the symptom list while I'm picking the symptoms. It does seem necessary for this kind of thing, because I'm not sure if someone would be able to just pick appropriate symptoms right off the bat from their mind. It's just difficult to go find certain things."

Finally supporting this need for changes in the mobile application are statements from Sara, who stated, “I don’t know if you can make of the [problems] more specific, or if they’re meant to be more general.” “I don't really think that it [the mobile application] changed my treatment and referral aspect” and finally, by Shannon, who relayed:

> “That it doesn’t automatically save” “I guess like the scrolling through the different questions, maybe being able to like search just for specific problems on the patient problem list” Field notes: The debriefing screen did not always work.”

Minor theme emerging. A minor theme emerged from Kerry and Charlotte that the application supported repeated practice. This theme was supported by Kerry, when she stated, “I don't want to use this word in a bad way, but like the redundancy of the app, and you continually do it over and over again. I guess, it will hone your clinical reasoning skills,” and finally by Charlotte, when she stated, “I like it for practice. I think it's the best way to go through scenarios and figure things out.”

Conclusion: Summary of The Findings

The mobile application was impactful to all participants without respect to demographic factors and produced two main changes related to student participants’ clinical reasoning. These changes are a progression in clinical reasoning abilities from *the pre-* to *post- task-based interview* and perceptions of student-participants on the impact of the mobile app on clinical reasoning. These changes will be summarized briefly and then subsequently discussed in relationship to the extant literature and research questions in Chapter 7.

Taking into account clinical reasoning, the mobile application impacted student-participants ability to: use higher order reasoning strategies, decrease the number of soft scaffolds needed during the task based interview process, improve the sequential order of the reasoning process, streamline the reasoning process by reducing the number or steps and the number of the skipped steps, and improve the ability to make a diagnostic decision, due to the ability to use higher order reasoning strategies with a refined sequence of reasoning. Further changed amongst student participants were the thematic statements regarding attitudes towards supporting factors for clinical reasoning. In spite of these changes produced by the mobile application, the mobile application did not appear to make changes in the clinical decisions made towards treatment appropriateness as expressed during the task-based interview.

The last finding of the study is related to the perceived support provided by the mobile application for the reasoning process. Student-participants identified that the mobile application was impactful in three ways: structuring the process of examination related to process management and sense making related to the disciplinary strategy for problem solving, supporting gains in increased knowledge, and supporting increasing the ability to focus on and identify the problem. Further identified by participants was that the mobile application supported articulation and reflection, and the mobile application needed changes to better support the reasoning process. A minor theme identified related to the impact of the mobile application was that it allowed repeated practice.

Considered next, in Chapter 6, will be findings related to the second aim of the study, namely, what soft scaffolds present within the mobile application were relied upon most by physical therapist students as they were working through a series of three different cases while utilizing the mobile application. This aim will be considered to better delineate the full impact of the mobile application on student-participant’s clinical reasoning and changes that need to be made within the mobile application.

CHAPTER 6: FINDINGS RESEARCH QUESTION TWO

This chapter will explore the findings related to the second aim of the study, namely, what soft scaffolds present within the mobile application were relied upon most by physical therapist (PT) students as they were working through a series of three different cases while utilizing the mobile application. First presented within the chapter is the role of scaffolding design in technological environments as it relates to the application under study, in order to provide a rationale for the use of scaffolds within the mobile application. Next presented is the application design related to scaffolds that were available to provide support for student-participants clinical reasoning. This application design is presented in order to contextualize what scaffolds students were able to access during application use. Thirdly presented is how users typically would proceed through the application during application use in order to provide context for user interactions within the mobile application. Fourth, the data analysis process used to derive the results is described. Finally presented are the results as related to research question two, which was: What soft scaffolds present in the mobile application do physical therapy student-participants rely upon most often to inform the scientific clinical reasoning process, and how does that reliance change over three different practice sessions?

Application Scaffolding Design

Within this section, the role of scaffolding in technologically rich environments as it related to the design of the mobile application under study is presented. In order to better give context to the research question, two theoretical constructs, the Hypothetical-Oriented Algorithmic Framework for Clinicians (HOAC-II-1) (Rothstein, Echternach, & Riddle, 2003) and the Scientific Reasoning Framework Model (Quintana et. al., 2014), that were integrated into the mobile application to scaffold learning are presented and discussed in relationship to the scaffolding provided within the mobile application.

The Role of Scaffolding in Application Design

The mobile application under study integrated learner centered design to allow the mobile application to effectively support scientific clinical reasoning. This meant that two things occurred within the design process, first, identifying that PT students have difficulty with clinical reasoning and secondly, incorporating educational principles to design an intervention that would address problems encountered by PT students as they are reasoning. In viewing difficulties with clinical reasoning, the researcher identified, in congruence with the literature, that PT students often have difficulty with elements of clinical reasoning such as: formulating and evaluating hypotheses once they have gathered subjective and objective sources of information from the patient, using reflection during the course of examination and treatment, using effective reasoning strategies, gathering too much data by conducting too many tests, or having enough experience or knowledge to generate a hypothesis (Gilliland, 2014; Rothstein, Echternach, & Riddle, 2003, p. 463; Wainwright, et al., 2010; Doody & McAteer, 2002; Gilliland, 2014; Hendrick, Bond, Duncan, & Hale, 2009). A second problem identified in relationship to these problems was a lack of on-demand knowledge support to support the scientific clinical reasoning process in the classroom or clinic.

In considering how to best support scientific clinical reasoning, and address problems that PT students have when learning to clinically reason, one solution proposed was to provide developmental scaffolds for the scientific reasoning process, via a mobile application. The reason for this proposing this solution was twofold. First, a mobile solution was proposed to provide personalized learning to PT students who were learning to perform scientific clinical reasoning at the point where reasoning was occurring, the classroom, or clinic. The second reason for providing this solution was to provide a method for mediating the learning of scientific clinical reasoning based upon social constructivism. More specifically, the use of a social constructivist stance allowed support to be given for providing a framework that presents knowledge at an appropriate time, and thus, permits learners to progress from initial, limited engagement in complex modes of problem solving into different modes of thinking that allow more complex problem solving (Mahn, 1999; Verenikina, 2003).

From the perspective of social constructivism, the concept of scaffolding emerged. Scaffolding within education in classroom and educational technology contexts has been described as “expert support for a novice’s learning” (Sharma & Hannafin, 2007). This support may be utilized as a means to move a learner who is developing certain problem-solving skills like clinical reasoning, to a higher level of problem solving, initially by providing explicit instruction, followed by decreasing supports (scaffolds) as the learner becomes more independent (Bruning et al., 1999). Within technology enhanced environments, the technology functions to provide expert-based scaffolding to support cognitive tasks such as managing cognitive load, supporting knowledge, or assisting with metacognitive processing (Sharma & Hannafin, 2007). These scaffolds may be provided in a fixed, or non-negotiable manner (hard), or in a contextually sensitive or on-demand (soft) manner, similar to the supports provided by a clinical instructor at the point of care (Sharma & Hannafin, 2007). While the role of scaffolding in technologically rich environments has not been considered extensively within PT education to facilitate complex problem solving, like that used in scientific clinical reasoning, studies within education have supported its use for scientific reasoning. These studies support that the incorporation of scaffolds for scientific reasoning increased ability to: plan and choose a strategy for problem solving, seek knowledge support and gain knowledge through provided scaffolding, monitor the process of decision making through reflection and metacognition, engage more deeply with content, successfully engage in more efficient and effective discipline-related decision-making, and formulate hypotheses and solutions to problems (Azevedo, Cromley, & Seibert, 2004; Brush & Saye, 2002; Quintana et al., 2004). These effects are primarily demonstrated when the computer aided learning environment is highly structured (uses a problem framework) and focuses upon the cognitive and metacognitive processes of solving ill-defined problems (Azevedo, Cromley, & Seibert, 2004.) Further support is also found for scaffolding scientific reasoning using case-based contexts in supporting the articulation of problem focused process, eliciting recall of information, and improving ability to problem solve when different case contexts were presented (Demetriadis et al., 2008).

Therefore, considering the challenges that PT students have when performing scientific clinical reasoning, and the support provided by scaffolding for supporting scientific (hypothetical deductive) reasoning processes, a case-based mobile application was designed to support learners' needs. This meant that the application was designed to support intentional learning of the processes of scientific clinical reasoning by providing scaffolds to the reasoning process. This scaffolding was provided within the case-based mobile application by the integration of two frameworks, the HOAC II-1, and the Scientific Reasoning Framework Model. Each of these models and their integration into the mobile application will be presented next.

The HOAC-II-1 and Scaffolding Within the Mobile Application

Within the mobile application, a scientific clinical reasoning framework was utilized to structure and provide an explicit scaffold to the process of clinical reasoning: the HOAC II-1. Within application design, this framework provided a disciplinary based, algorithmic structure to the scientific reasoning process. By using the framework in this way, it was possible to make the disciplinary strategy apparent for learners through the use of application features or buttons designed into the mobile application. Table 6.1, below, describes the application feature or button designed into the mobile application, the application action taken when the application feature or button is accessed, and the part of the HOAC II-1 framework that is supported with the application action, feature, or button.

Table 6.1. Application Features and HOAC-II-1 Framework Supported.

Application Feature/Button	Application Action	Framework Supported
Scenario (pre-built)	Application provides initial data to student	Collecting Initial Data
Application popups "What is your rationale"	HOAC not followed in order	Supports sequence of HOAC II process
Patient History	Application provides a link to information about information to be gathered within the patient history	Supports knowledge needed for clinical reasoning
About HOAC	Application provides a link to information about the HOAC II framework	Supports knowledge about the HOAC II framework
About Conditions	Application provides a link to information about conditions covered by the application	Supports knowledge needed for clinical reasoning
About Tests	Application provides a link to information about tests needed to evaluate the patient problem	Supports knowledge needed for clinical reasoning
Hint	Application gives a hint about the next step in the evaluative process	Supports student in the process implementation of the stepwise framework of the HOAC II
Subjective Interview Button	Subjective Interview Button: Enter data from referral, case information given, observation, and subjective interview	Collecting Initial Data

Table 6.1. (continued).

Record Data Button	Generate Patient Identified Problems List: Application will ask the user to create a list of patient problems /symptoms to which the student can refer later, open text box for notes for problems/other items the student finds significant	Generate Patient Identified Problems List
Initial Hypothesis	Application will ask the user to input an initial working hypothesis and other hypotheses that are under consideration to be evaluated	Formulate Examination Strategy
Objective examination	Application will provide a list of possible tests based upon symptoms, help will be provided for knowing what the tests are, alternate symptoms, or other questions that they want to know the answer to.	Formulate Examination Strategy, Conduct the Examination
View results	Application will list positive and negative tests in summative form, symptoms that they looked for, patient identified problems, and hypotheses.	Refine Hypotheses, carry out Additional Tests needed
Generate Problem List	Application will provide a list of patient and non-patient identified problems/ from tests allow user input of other detected problems; application will support user by giving a likelihood of diagnoses based upon inputs	Add non-patient Identified Problems
Final Hypothesis	Application will give a list of possible patient diagnoses, User will provide a rationale for selecting the diagnosis, ask for further non-patient identified problems, and for a treatment/referral decision and rationale	Generate a hypothesis, Refine Problem List

Further illustrating the integration of this framework are two exemplars from the finalized application that demonstrate the hard (fixed, non-negotiable) scaffolding of the HOAC-II-1 framework. These are presented as Figures 6.1and 6.2. Figure 6.1, below, demonstrates the scenario display page, which is a scaffold that pertains to the initial hypothesis step in the framework. Figure 6.2, below, depicts the buttons that pertain to the HOAC II-1 framework steps, which allowed the user to proceed through the framework in an ordered manner, and permitted access to a page to enter data pertaining to each step, on a screen specific to that step.

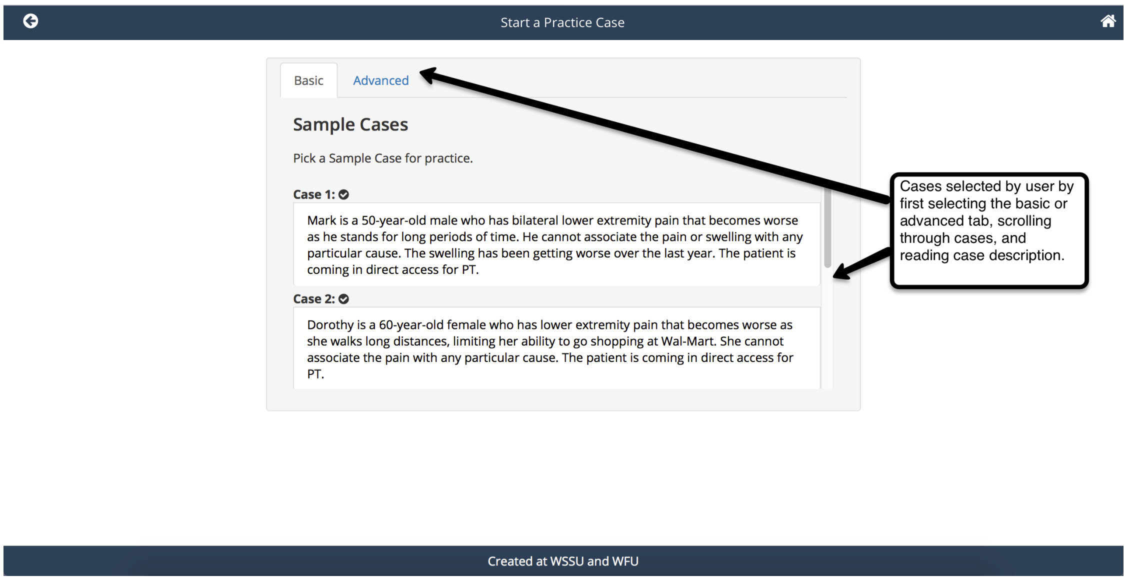


Figure 6.1. Scenario Selection Panel (Collect Initial Data).

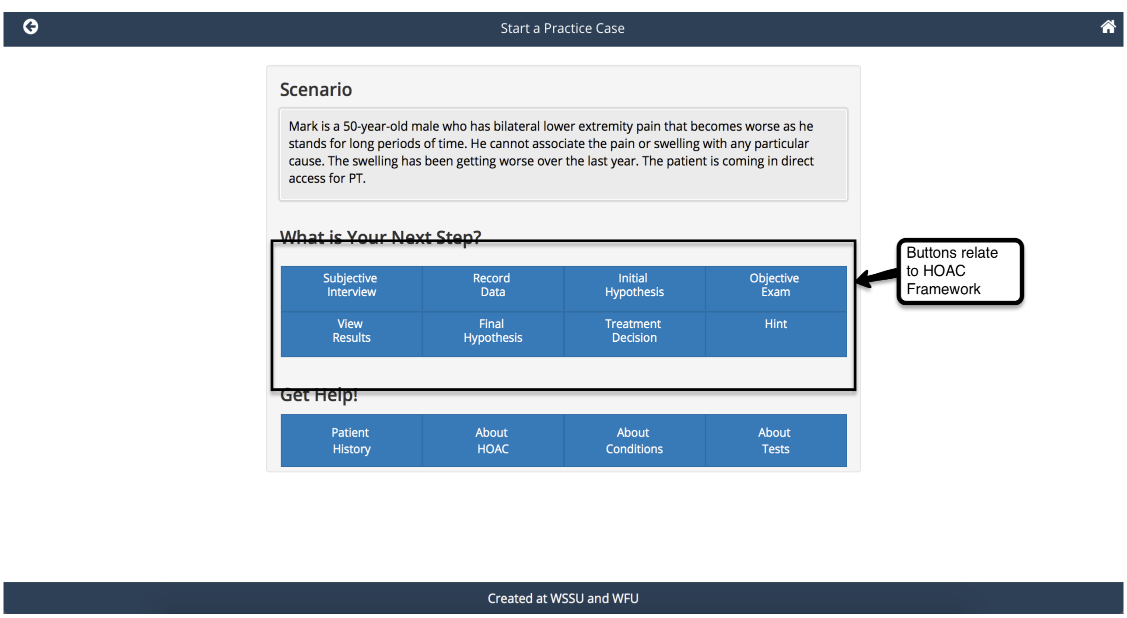


Figure 6.2. HOAC-II-1 Framework Buttons (Identify Steps in the Framework).

Scientific Reasoning Framework Model and Integration into the Mobile Application Via Soft Scaffolds

Another framework integrated into the mobile application was a model that advocated for scaffolds needed to support scientific reasoning, posited by Quintana (2004). There were three reasons for choosing this model. First, this model identified and chosen from the profession of education, since limited data exists on what scaffolds are needed to support scientific clinical reasoning in physical therapy. A second reason for choosing this scaffolding model is that scientific clinical reasoning and scientific reasoning follow similar processes. A third and final reason for using this model was to allow an investigation of what types of soft scaffolds are supportive for PT student scientific clinical reasoning in the implementation and evaluation steps of the ADDIE model, since this is a gap within the literature.

Use of this model informed the development of hard (fixed) scaffolds for process management to return data to users to manage cognitive load and soft (contextually-dependent or on-demand) scaffolds (Sharma & Hannafin, 2007) for both sense- making and articulation and reflection. Following the recommendation of Quintana, et al. (2004), soft scaffolds were constructed to support just-in-time knowledge support (for sense making) or by having users monitor their actions within the mobile application (to foster articulation and reflection). These two types of scaffolding were chosen to be provided on demand for two reasons. One reason is that these scaffolds (knowledge support and reflection-in action) may be needed depending on the context of the reasoning process, and therefore are not always required to be present. The second reason that these types of soft scaffolds were chosen is that novice PT practitioners and students often need support for sense making and articulation and reflection when they are engaging in scientific clinical reasoning, due to the difficulties they have when first learning to reason.

Table 6.2, below, describes how soft scaffolds were integrated into the mobile application and how they relate to the scaffolding framework model posited by (Quintana, 2004). In the table, the application scaffolding features are matched to the scaffolding design framework model in the next three columns, by relating them to the scientific inquiry component (sense making or articulation and reflection), the guideline that is addressed by that scaffold, and the scaffolding strategy utilized.

Table 6.2. Soft Scaffolds Integrated into the Mobile Application and Relation to the Scaffolding Design Framework Model (Quintana, 2004).

Application Feature	Scientific Inquiry Component	Guideline	Scaffolding Strategy
Cues to indicate out of order steps in the framework through popup when HOAC II-1 sequence is not followed, or when data not entered.	Sense making	Guideline 2: Organize tools and artifacts around the semantics of the discipline.	2a. Make disciplinary strategies explicit in learner's interactions with the tool.
Reflection on steps taken out of order—popup when step is skipped	Articulation and reflection	Guideline 7: Facilitate ongoing articulation and reflection.	7b. Provide reminders and guidance to facilitate productive monitoring.
Help feature for "Patient History"	Sense making	Guideline 1: Use representations and language that bridge learner's understanding.	Guideline 1c. Embed expert guidance to help learners use and apply content.

Table 6.2. (continued).

"Hint" button	Sense making	Guideline 1: Use representations and language that bridge learner's understanding. Guideline 2: Organize tools and artifacts around the semantics of the discipline.	1c. Embed expert guidance to help learners use and apply content. 2a. Make disciplinary strategies explicit in learner's interactions with the tool.
Help feature for "About HOAC"	Sense making	Guideline 1: Use representations and language that bridge learner's understanding.	Guideline 1c. Embed expert guidance to help learners use and apply content.
Help feature for "About Tests"	Sense making	Guideline 1: Use representations and language that bridge learner's understanding.	Guideline 1c. Embed expert guidance to help learners use and apply content.
Help feature for "About Conditions"	Sense making	Guideline 1: Use representations and language that bridge learner's understanding.	Guideline 1c. Embed expert guidance to help learners use and apply content.
Arrows beside tests in objective examination screen that, when tapped, links the user to information about that test.	Sense making	Guideline 1: Use representations and language that bridge learner's understanding.	Guideline 1c. Embed expert guidance to help learners use and apply content.

The scaffolds provided in the table above, were present either when triggered by a user action (an out of order step, missed entry into the app) or by user choice (on demand, to gain more information for disciplinary knowledge support). Figures 6.3 and 6.4, describe scaffolds that were triggered by a user action (or a failure to act). More specifically, Figure 6.3, below, presents an example of the sense making cue that pops up when a step is not completed in full, as explained in the table above. Further providing support for an out of order step, Figure 6.4, below, presents the soft scaffold for articulation and reflection that asks the user to state their reason for pursuing an out of order step in the framework.

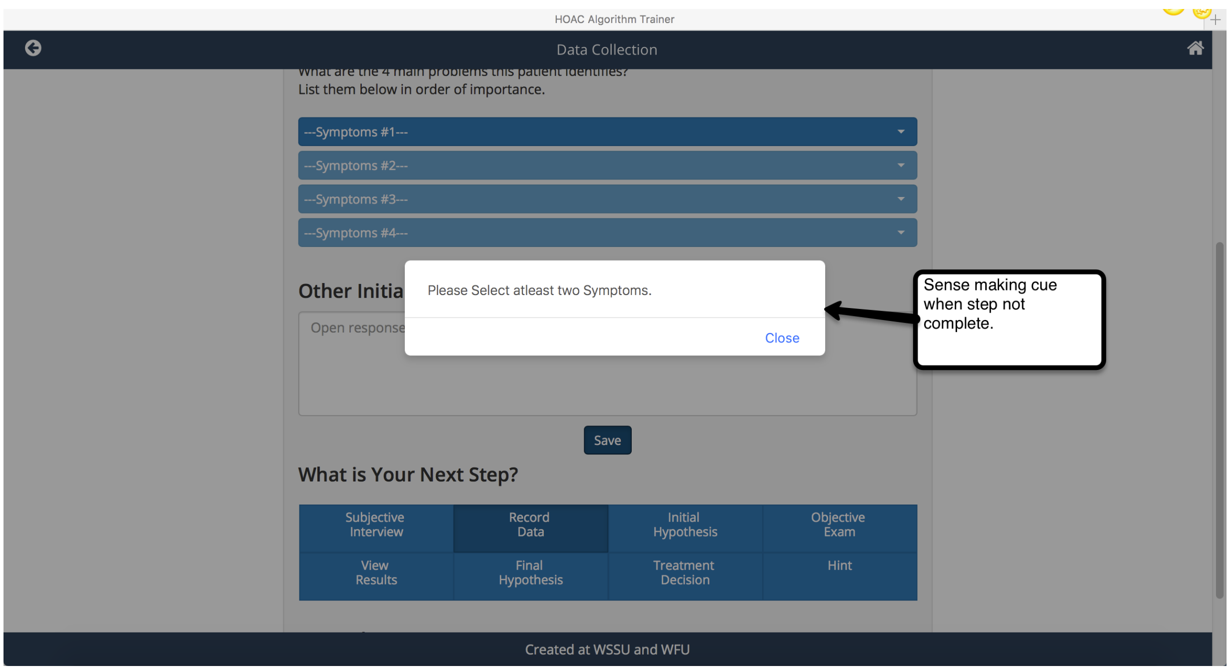


Figure 6.3. Sense Making Soft Scaffold for Incomplete or Skipped Step.

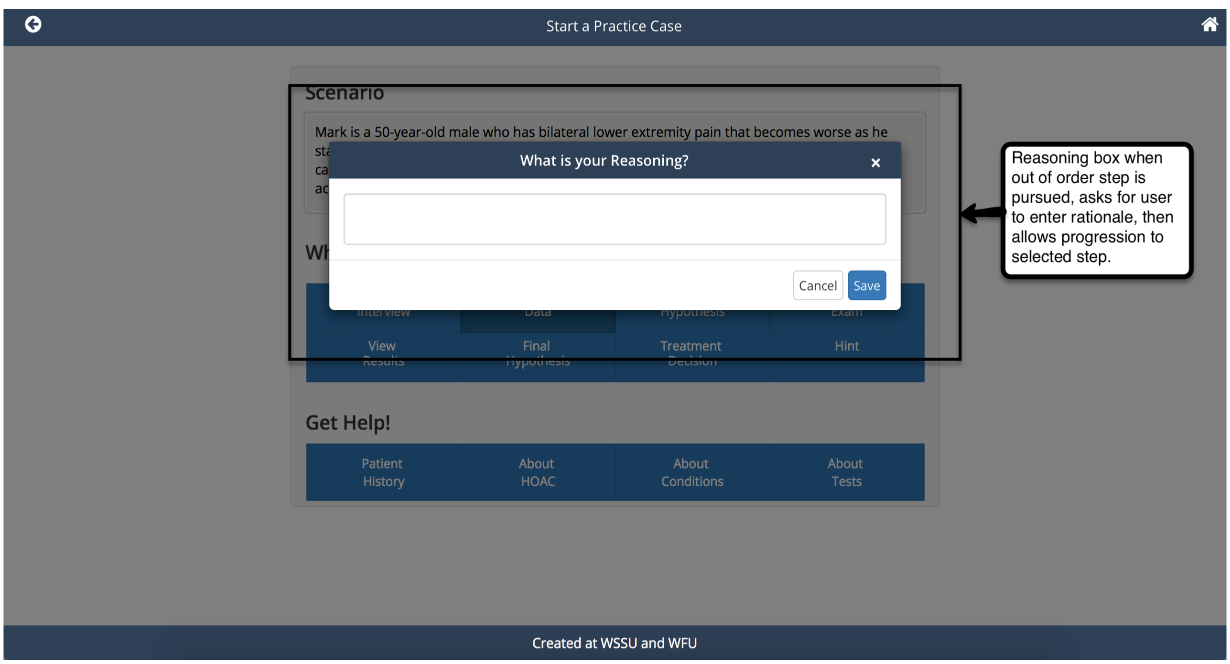


Figure 6.4. Out of Order Step Popup for Sense Making and Articulation and Reflection.

Figures 6.5 through 6.9 demonstrate the types of disciplinary knowledge scaffolds that were available to users within the mobile application if the user chose to select them. This knowledge support could be accessed by virtual buttons that were located at the bottom of the "start a practice case," "subjective interview," "record data," "initial hypothesis," "objective exam," and "view results" screens. To better contextualize these scaffolds, Figure 6.5 presents the "Patient History" soft scaffold, that provided support for the collect initial data step in the framework. Figure 6.6 demonstrates the "Hint" button, that gave a cue to the user about the next step in the disciplinary framework. Within Figure 6.7, the help feature "About HOAC" is demonstrated, that was available to provide support to users by providing information about the HOAC-II-1 framework. Figures 6.8 and 6.9 present the help features for about conditions and about tests that provided discipline-specific, just-in time knowledge support. Finally illustrated, in Figure 6.10, is the arrow beside the tests, located on the objective examination screen, that when tapped, provided discipline-specific knowledge support related to the specific test located by the arrow.

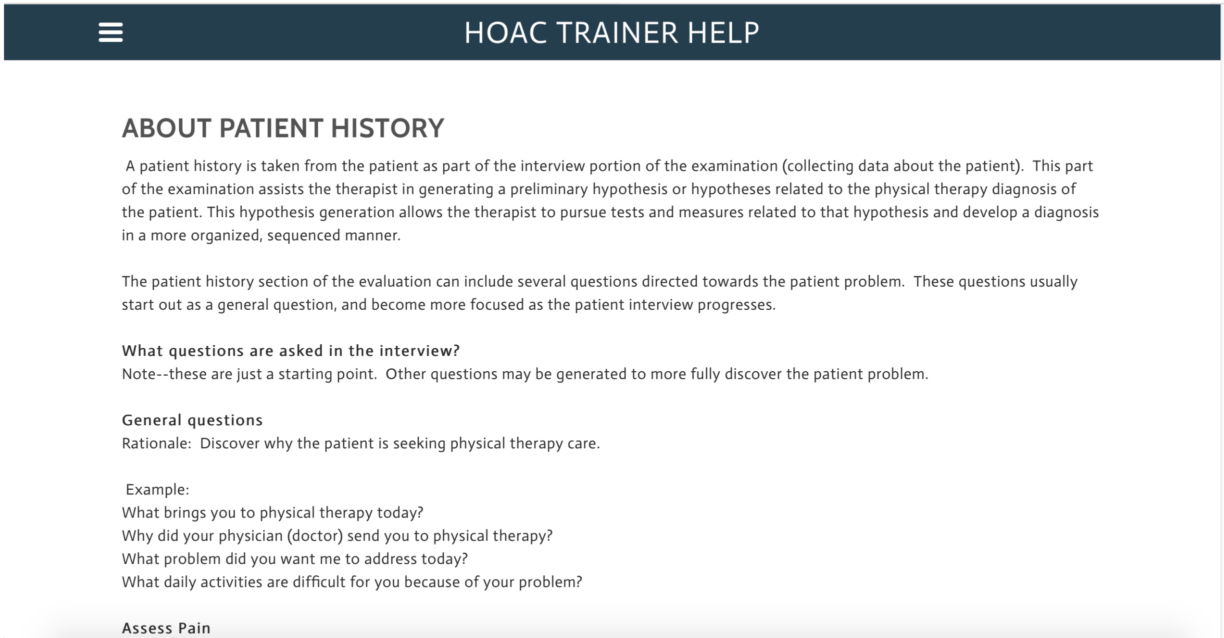


Figure 6.5. About Patient History

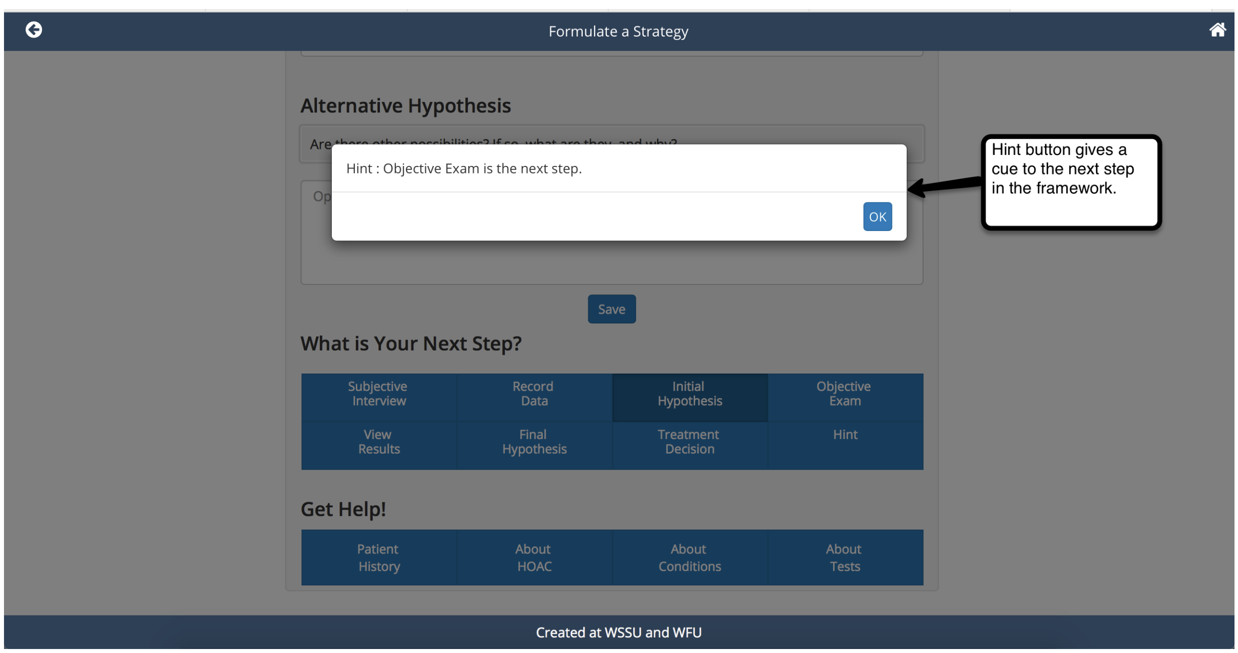
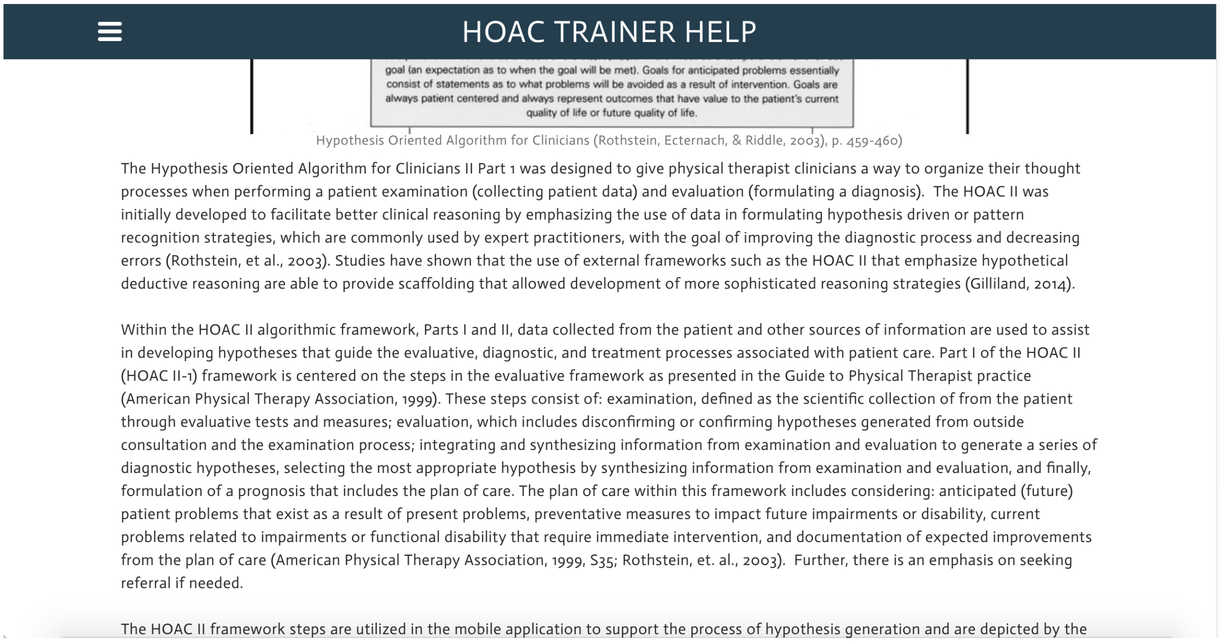


Figure 6.6. Hint Button.



HOAC TRAINER HELP

goal (an expectation as to when the goal will be met). Goals for anticipated problems essentially consist of statements as to what problems will be avoided as a result of intervention. Goals are always patient centered and always represent outcomes that have value to the patient's current quality of life or future quality of life.

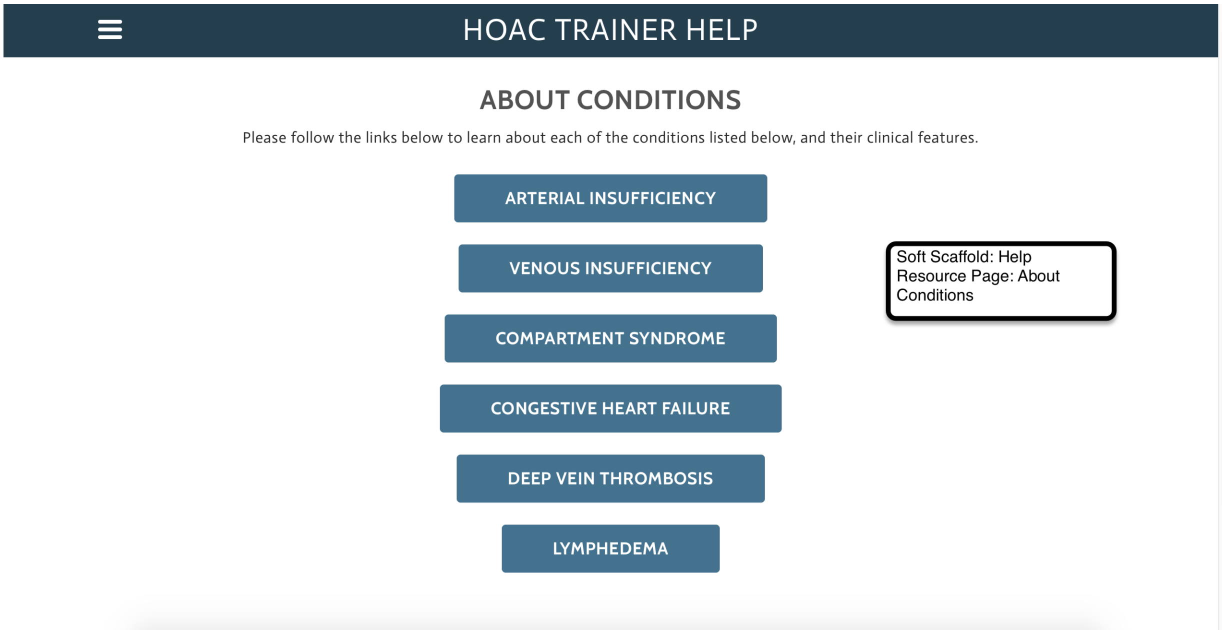
Hypothesis Oriented Algorithm for Clinicians (Rothstein, Ecternach, & Riddle, 2003), p. 459-460)

The Hypothesis Oriented Algorithm for Clinicians II Part 1 was designed to give physical therapist clinicians a way to organize their thought processes when performing a patient examination (collecting patient data) and evaluation (formulating a diagnosis). The HOAC II was initially developed to facilitate better clinical reasoning by emphasizing the use of data in formulating hypothesis driven or pattern recognition strategies, which are commonly used by expert practitioners, with the goal of improving the diagnostic process and decreasing errors (Rothstein, et al., 2003). Studies have shown that the use of external frameworks such as the HOAC II that emphasize hypothetical deductive reasoning are able to provide scaffolding that allowed development of more sophisticated reasoning strategies (Gilliland, 2014).

Within the HOAC II algorithmic framework, Parts I and II, data collected from the patient and other sources of information are used to assist in developing hypotheses that guide the evaluative, diagnostic, and treatment processes associated with patient care. Part I of the HOAC II (HOAC II-1) framework is centered on the steps in the evaluative framework as presented in the Guide to Physical Therapist practice (American Physical Therapy Association, 1999). These steps consist of: examination, defined as the scientific collection of from the patient through evaluative tests and measures; evaluation, which includes disconfirming or confirming hypotheses generated from outside consultation and the examination process; integrating and synthesizing information from examination and evaluation to generate a series of diagnostic hypotheses, selecting the most appropriate hypothesis by synthesizing information from examination and evaluation, and finally, formulation of a prognosis that includes the plan of care. The plan of care within this framework includes considering: anticipated (future) patient problems that exist as a result of present problems, preventative measures to impact future impairments or disability, current problems related to impairments or functional disability that require immediate intervention, and documentation of expected improvements from the plan of care (American Physical Therapy Association, 1999, S35; Rothstein, et. al., 2003). Further, there is an emphasis on seeking referral if needed.

The HOAC II framework steps are utilized in the mobile application to support the process of hypothesis generation and are depicted by the

Figure 6.7. About HOAC



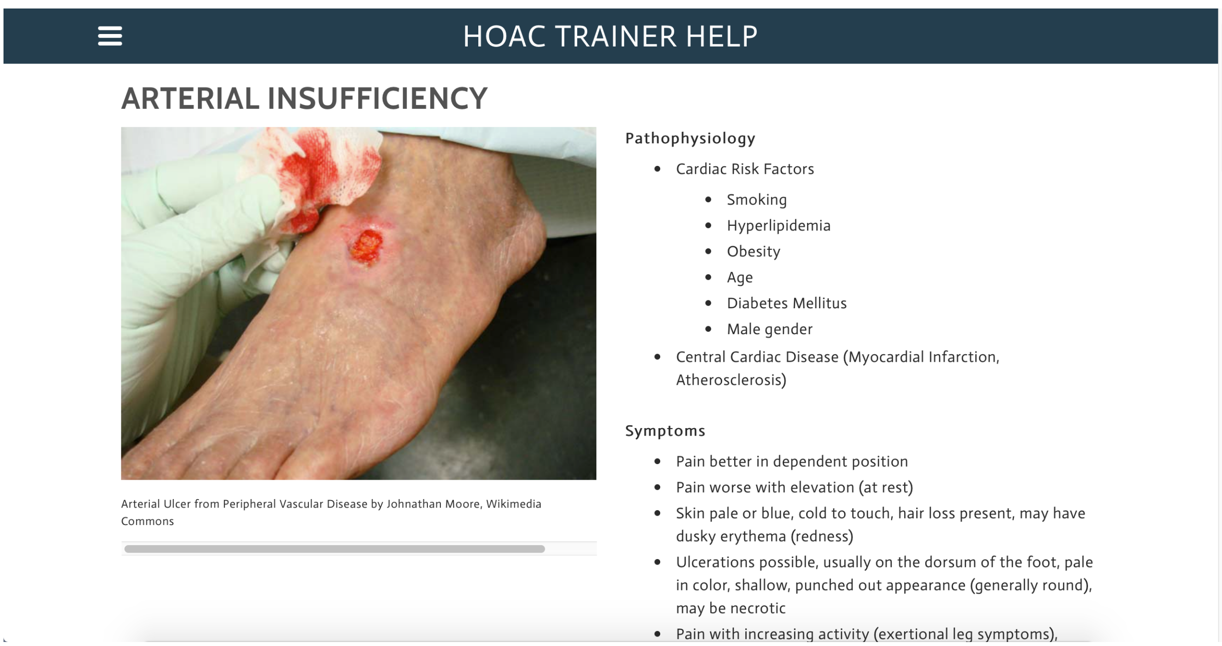


Figure 6.8. Sense Making Soft Scaffold When Buttons Accessed: Help for About Conditions Access Screen and Exemplar.

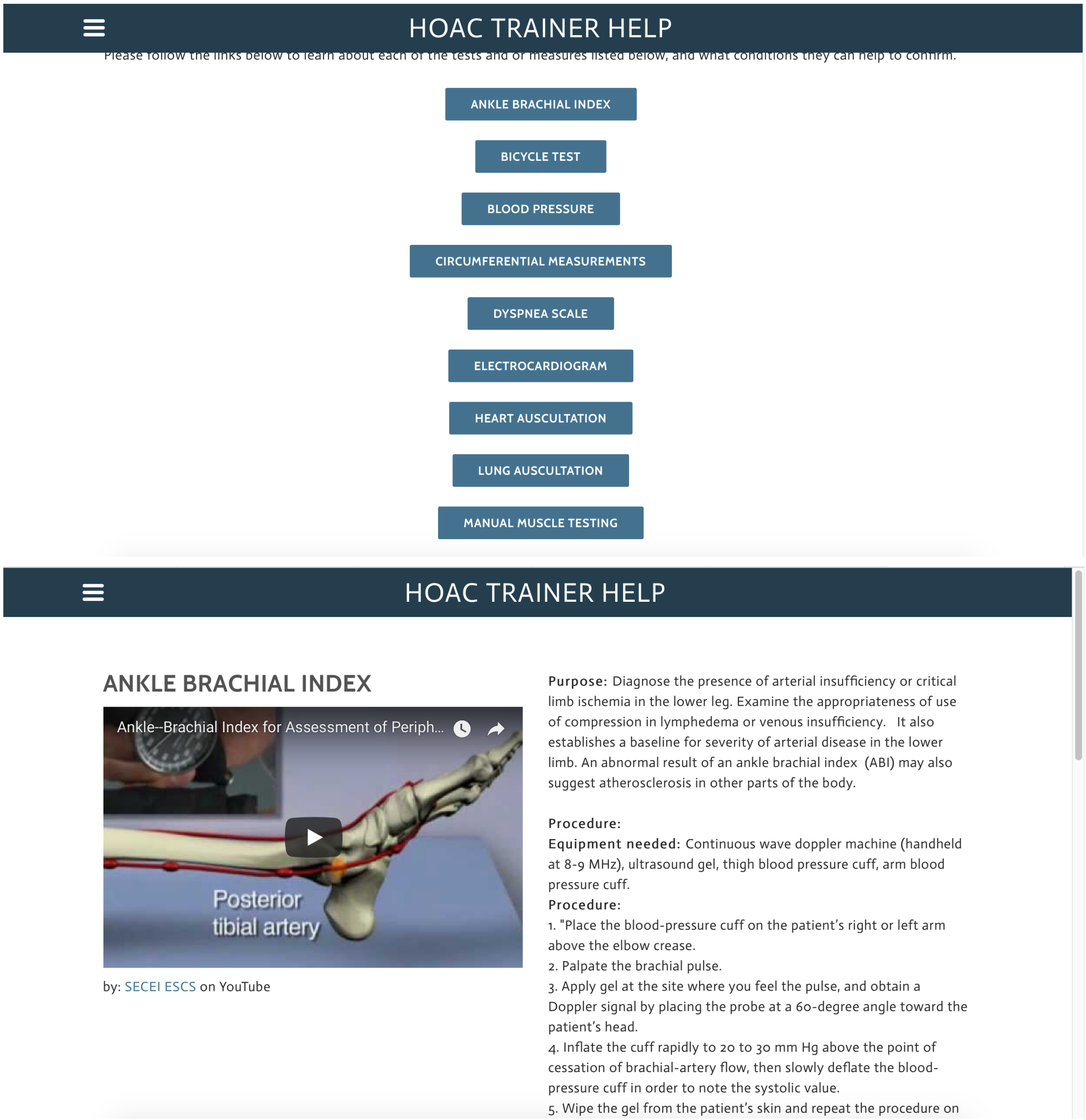


Figure 6.9. Sense Making Soft Scaffold When Buttons Accessed: Help for About Tests Access Screen and Exemplar.

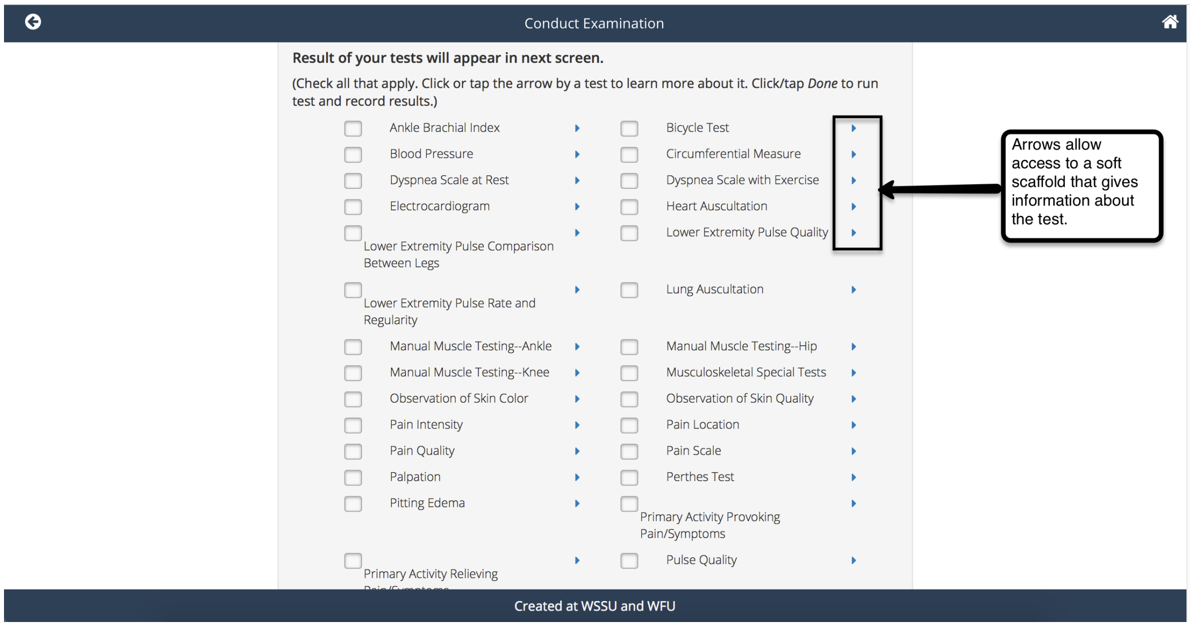


Figure 6.10. Arrow Beside Tests for Knowledge Support About Tests.

Ideal Sequence of Problem Solving Using the Mobile Application

Presented subsequently is the ideal sequence, as related to the HOAC-II-1, for user interaction with the mobile application under study in order to contextualize the steps undertaken by users when they worked within the application. During all sessions with the mobile application, after logging in with a unique, de-identified login, the participant selected a practice scenario case that received expert review, specific to lower-extremity vascular disorders. Users were allowed to select a case of their choosing from the case selection panel by tapping on the basic or advanced case tab (judged to be basic or advanced by expert reviewers), scrolling through the introductory case descriptions provided on each tab, and reading the case description. However, student participants were not allowed to repeat a completed case during any intervention session in order to limit practice effects. This case selection process is depicted in Figure 6.11, below.

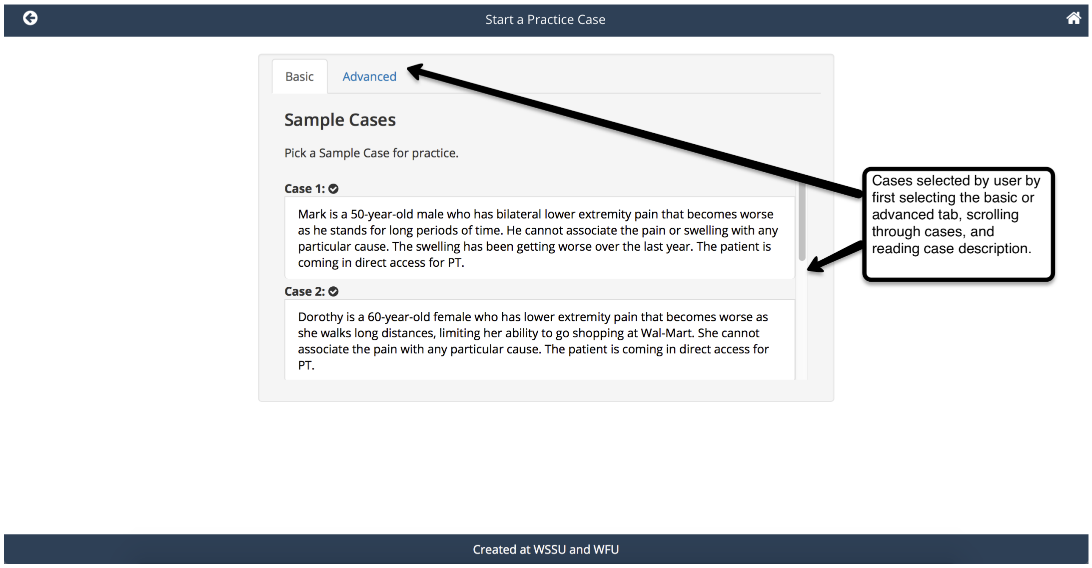


Figure 6.11. Case Selection Process.

Following case selection, in which all student-participants selected a basic case, a set of standardized buttons was presented with the case information. These buttons were consistently present on each subsequent screen except for the screens for diagnosis and treatment and for debriefing. Within the application, the buttons allowed the participant to select a step in the HOAC II-1, and therefore access screens pertaining to that particular step. These buttons are highlighted in Figure 6.12, below, and are numbered within the figure in the ideal sequence for problem solving, as outlined in the HOAC—II-1 framework.

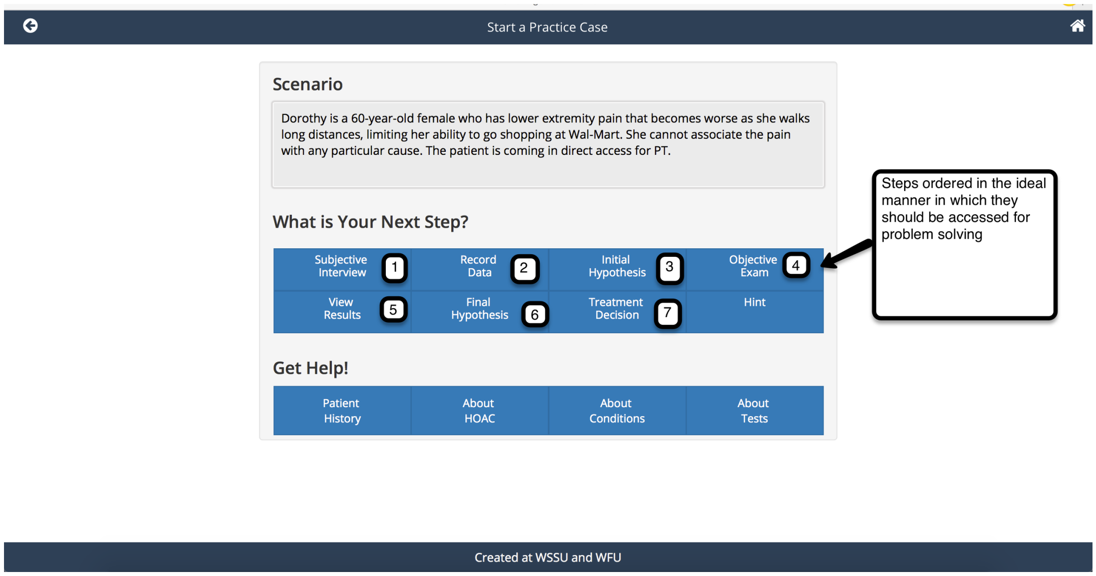


Figure 6.12. Sequential Order of Problem Solving as it Related to Buttons in the Mobile Application.

After student participants completed the steps in the process, a debriefing screen was presented. This screen presented the diagnoses and tests that the participant selected, and also provided information from an expert practitioner listing the actual diagnosis, the tests that should have been selected, the most appropriate treatment decision, and the rationale for the treatment or referral decision. Also displayed on the debriefing screen was an open-ended text box that allowed the user to enter a reflection on improvements needed for the next time. Upon entering their reflection on performance, the participant was able to choose to select another case, receive the case data by email, or save their data and exit. Following selection of one of the options, the reflection data was recorded to the database for later analysis.

Data Analysis Process

The ensuing section will first present the participant selection process utilized to purposefully select data to analyze to answer the research question. Secondly presented is the data analysis process utilized.

Participant Selection

Data from the time stamps collected during mobile application use were analyzed to determine total time spent utilizing the mobile application during the second, third and fourth sessions, with the goal of identifying the most active users of the mobile application, since these users most likely accessed the most application features. This total time is noted in Table 6.3.

Table 6.3. Time Spent by Participant Using the Mobile Application, Across Sessions.

Participant	Time Session 2	Time Session 3	Time Session 4	Total Time
Sara	18.5 minutes	11 minutes	15 minutes	44.5
Bryan	13 minutes	10 minutes	10.5 minutes	33.5
Marcus	15 minutes	8 minutes	9 minutes	32
Shannon	32.25 minutes	39 minutes	15 minutes	89.25
Kerry	13 minutes	28 minutes	26.5 minutes	67.5
Charlotte	29 minutes	12 minutes	20.5 minutes	61.5

Data Analyzed to Obtain Thematic Results

From the time stamp data, three individuals Shannon, Kerry, and Charlotte's video-based data were purposefully selected for analysis based upon spending the most time within the mobile application. For each of the three active users, and amongst the three users a within-session and across-session and collective session approach was utilized for data analysis, with four goals: (1) of detecting changes in the use of soft scaffolding provided by the application across sessions, (2) understanding how the application supported the sequence of the reasoning process across sessions, (3) determining whether there were possible obstacles or benefits to soft scaffolds utilized by determining their utility in supporting the reasoning process, and (4) determine based upon user interaction what changes needed to be made in the mobile application.

For the data collected in this study during mobile application use, each user session was treated as a narrative unit of analysis (Polkinghorne, 1995). Data from each unit of analysis included the various types of data that were collected: annotations of video data and/or screenshots to depict student-participants' work within the application, descriptions of physical gestures or actions undertaken by student-participants while using the mobile application, and analytics from the mobile application (Lee & Hollebrands, 2006).

From each narrative unit of analysis, data related to human activity viewed through a lens of "purposeful engagement" (Polkinghorne, 1995, p. 5) were transcribed in the order in which they occurred from the data sources noted above. Purposeful engagement was defined as "goal-oriented behavior to which effort is focused or directed" following the methodology of Lee and Hollebrands (2006, p. 256). From each goal-oriented behavior, participant actions were coded into the type of goal-oriented behavior pursued related to either the use of algorithmic sequence of the HOAC-II-1 and/or use of soft scaffolds within the mobile application. For the purposes of this study, a HOAC-II-1 or scaffolding based goal-oriented behavior was identified as: (1) pursuing a goal via action or thought related to the HOAC framework by clicking on a step or entering data into the application, (2) pursuing a goal via action or thought related to accessing soft scaffolds in the application, (3) engaging in articulation or reflection by entering additional data, (4) entering a rationale for the decisions made, or (5) engaging with process management features of the application.

Data related to the goal-oriented behavior were further analyzed by the HOAC II-1 step pursued as defined previously as related to the framework button accessed in the mobile application. To further analyze the reasoning process, behavior related to the HOAC II-1 framework was coded by using the codes defined in the *a priori* coding manual (out of HOAC order, in HOAC order) to determine whether the sequence of the algorithm was being followed during application use. Any out-of-sequence event was transcribed from the video data and the user data (which consisted of the rationale associated with that event, if entered, and this transcription was subsequently analyzed using inductive coding. A further analysis was conducted, based upon the sequences followed in the mobile application, to determine what changes needed to be made within the mobile application.

A further analysis of the goal-oriented behavior was conducted to discover which scaffolding features were accessed by student-participants. These behaviors were coded to define the type of scaffolding accessed by the codes defined in the scaffolding framework applied to the mobile application, as previously described (sense making, process management, or articulation and reflection). A further analysis of these events was undertaken to identify what features were accessed, and when, during the reasoning process by corroborating the scaffolding feature to what step in the HOAC II-1 was being pursued at that time. Similar to Lee and Hollebrands (2006), data on which application features were accessed was coded as supportive or non-supportive. A feature was coded as supportive if it assisted the participant in accomplishing the clinical reasoning goals, in proceeding through the algorithmic framework, and in working toward the end point of establishing a correct diagnostic decision and making a correct decision toward treatment appropriateness. A feature was coded as unsupportive if it did not assist in the reasoning process, did not help the participant establish a correct diagnosis or treatment decision, or affect the participant's actions within the mobile application.

Finally, correctness of the hypothesis and treatment appropriateness as well as rationales were corroborated with the sequence and support needed, using a collective case approach. The purpose of this analysis was to detect whether a participant's orientation to the HOAC II-1 framework, use of a particular reasoning strategy, or need for support for clinical reasoning had an effect on their hypotheses generated or their decisions and rationales towards treatment and treatment appropriateness.

Findings: Soft- Scaffolding Use by Student Participants and Implications for Application Re-Design

Within and across case findings from each purposefully selected participant will be presented in order to understand how the application supported the sequence of the reasoning process across sessions. From the sequence followed, implications for application re-design will be provided. Secondly presented will be the types of soft scaffolds accessed by participants, the step in the framework in which they were accessed, and the determination of how supportive scaffolds were for the reasoning process. Third, corroboration between the use of soft scaffolds and the sequence followed during application use will be provided, using a collective case approach. Finally, a summary of the effects of scaffolding and a summary of recommendations for application design will be given.

Trustworthiness

Trustworthiness for the findings provided in this chapter was ensured by member checking, where each participant agreed to the findings related scaffolding use and the impacts of scaffolding, by stating, “I agree,” or “That’s what I did.” To additionally ensure trustworthiness of the findings in this chapter, data triangulation between application back end data, researcher field notes, video data of participant actions, and video screencasting data was utilized.

Within Case Findings: Order of the Reasoning Process During Application Use

The findings for the order of the reasoning process will be presented using a within case approach in this section, beginning with Kerry, then Charlotte, and concluding with Shannon. Presented for each participant will be a figural representation of the reasoning process undertaken by each of the participants while they were using the mobile application in sessions two, three and four. Secondly presented will be a textual description and rationale for the order undertaken by participants while the mobile application was in use. To contextualize the information presented in this section, Figure 6.13, below, presents the ideal order of the process that should be followed during application use.

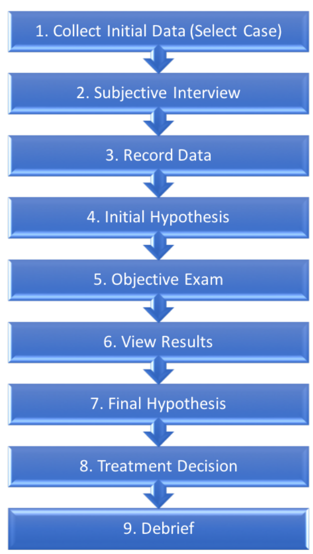


Figure 6.13. Ideal Order of the Steps for Reasoning in the Mobile Application.

Kerry. Presented in Figure 6.14, below, is Kerry's process that she followed during mobile application use over the three sessions. Within the figure, in order steps are depicted in blue, and out of order steps are depicted in orange. Following the figure, themes derived from the sequence followed by Kerry will be presented with a description of actions and rationales for the actions to support these thematic statements.

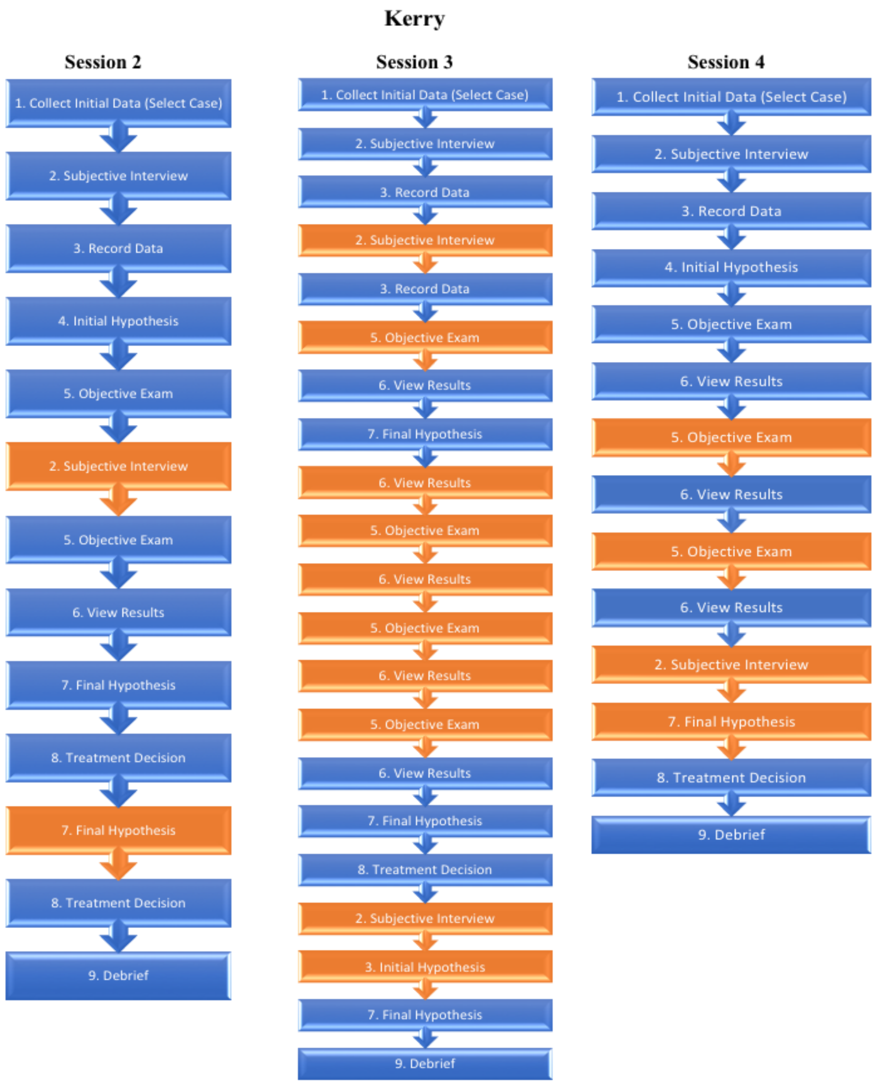


Figure 6.14. Kerry’s Order for Reasoning During Mobile Application Use.

Over the three sessions with the mobile application, Kerry had two out of order events in the second session, ten out of order events in the third session, and four out of order events in the fourth session. The decrease in out of order events from the third to fourth session may indicate a progression in the ability to sequence the reasoning process. Further implicated by the out of order events was Kerry's need to: gather more information during the subjective examination or objective examination steps that was prompted either by hard or supported by soft scaffolds, gain just-in-time knowledge support as evidenced by accessing the soft and hard scaffolds in the application, perform articulation and reflection (reflection on action) during the reasoning process, not skip steps in the diagnostic process, and finally, ensure that data entered into the application was saved. These assertions will be supported with a description of the out of sequence events and the rationale for these events.

Kerry had two out of order events during session two. The first out of order event occurred when she was accessing the objective examination screen, as a result of reading a hard scaffold that stated, "Are there any more questions that you want to ask the patient." After reading this scaffold, Kerry went from the objective exam to the subjective exam screen in an effort to obtain more information to guide her examination process. Her second out of order event was related to returning from the treatment decision screen to the final hypothesis screen in order to enter more data into the "add non-patient identified problems to the problem list," indicating a need for more articulation and reflection of the patient problem to focus her treatment strategy.

During the third session, Kerry increased in the number of out of order events in the third session with the mobile application, resulting in 10 out of order events with two main causes. The first cause of an out of order event was prompted by hard scaffolding on the record data screen that asked, "What are the four main problems this patient identifies?" After reading this hard scaffold, Kerry returned to collect more subjective information. Following this prompt assisted her in subsequently identifying more initial problems.

A second cause of the increase in out of order events during session three could have been due to not identifying or entering an initial hypothesis during the record data step. This lack of identification of an initial hypothesis resulted in multiple problems, which in turn resulted in the establishment of an incorrect final hypothesis (diagnostic decision). These problems will be detailed subsequently.

First, Kerry's lack of identification of an initial hypothesis first led her to request more objective tests than she needed to identify the diagnosis. The collection of more objective tests was evidenced by Kerry going back and forth between the view results and objective screen three times. In this process, Kerry utilized extensive scaffolds to support her knowledge about tests and conditions. A second challenge created by a lack of an initial hypothesis was that Kerry required more knowledge support to learn about the conditions represented in the application in order to provide a rationale for her diagnosis, as evidenced by going from the final hypothesis step to the subjective interview screen to access scaffolding buttons. A third challenge that was evident in her process was her uncertainty in the final diagnosis, as evidenced by using scaffolding to formulate her final hypothesis towards diagnosis instead of case information. During this process, she read about the pain description and features of the different diagnoses in order to collect information about them in order formulate her diagnosis (final hypothesis). The final problem identified was her lack of identification of an initial hypothesis, which resulted in an out of order step, because the application made her to go back and identify an initial hypothesis at the end of the reasoning process. This out of order step may have been caused by the application not forcing data entry into the initial hypothesis box.

Overall, Kerry did become more organized in her process in the final session, and reduced her number of out of order steps. Her first sequence of out of order steps was related to going from view results back to the objective examination to collect more data (two times), with a rationale of needing to confirm her diagnostic hypothesis. This confirmation of her diagnostic hypothesis was supported through scaffolding, in which she selected the about tests button/arrow beside the tests to gain more knowledge of what the tests diagnosed. The second out of order event noted that occurred during the fourth session was related not to clinical reasoning, but due the application not automatically saving data that was entered on the subjective examination tab.

Shannon. Presented in Figure 6.15, below, is Shannon's process that she followed during mobile application use over the three sessions. Within the figure, in order steps are depicted in blue, and out of order steps are depicted in orange. Following the figure, themes derived from the sequence followed by Shannon will be presented with a description of actions and rationales for the actions to support these thematic statements.

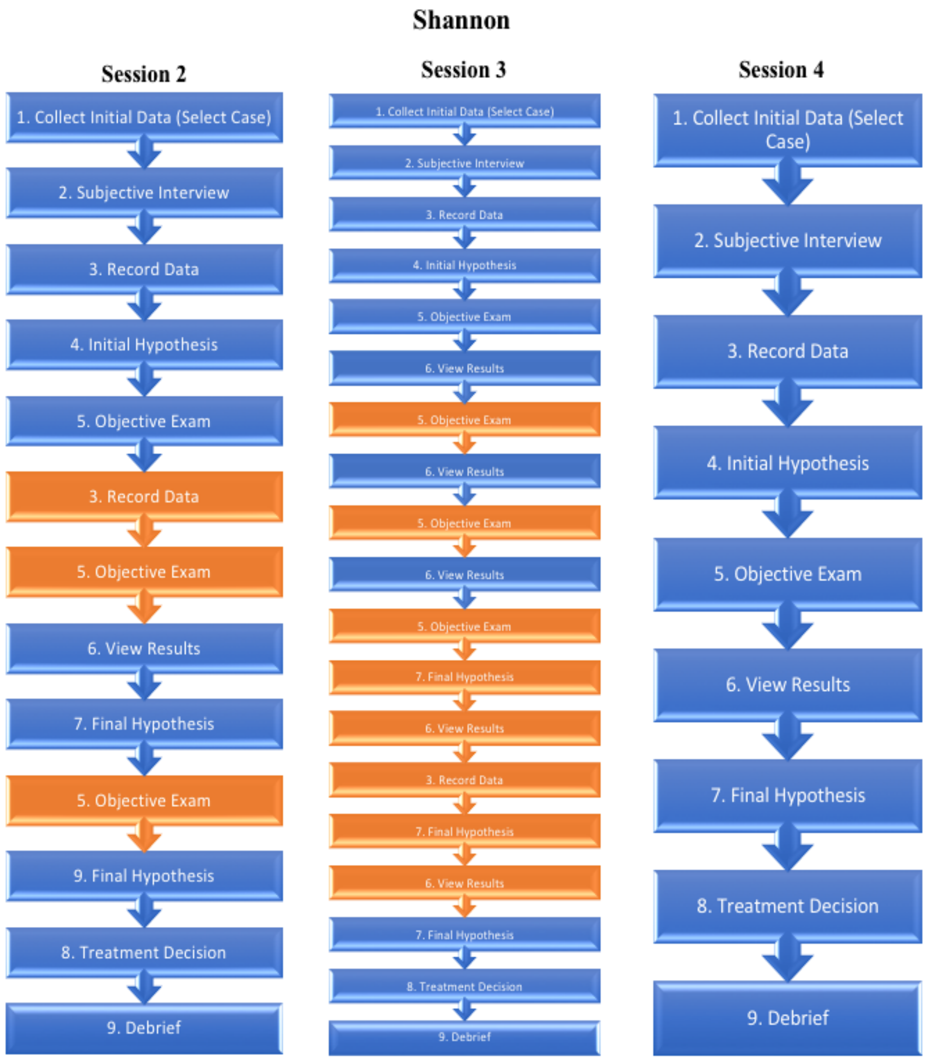


Figure 6.15. Shannon's Order for Reasoning During Mobile Application Use.

Over the three sessions with the mobile application, Shannon had three out of order events during session two, eight out of order events during session three, and no out of order events during session four. This change in the number of out of order events may indicate a progression in the ability to sequence the reasoning process, especially noting the decrease in out of order events from session three to session four. Further implicated by the out of order events is a need for the application to support reasoning thorough process management or knowledge support, or for Shannon to gain more information to help with the diagnostic process in the objective examination step. Each of the sessions will be described subsequently to present support for these assertions.

During the first session with the mobile application, Shannon had three out of order events. While working through the conduct the examination step, Shannon returned to the record data step to review subjective answers returned, indicating a need for process management to use subjective information to guide the generation of appropriate objective measures. Another out of order step was related to the view results step, in which she went back to the objective exam step to collect more tests, indicating a need for more tests to support her reasoning process in order to allow her to make a diagnostic decision. The final out of order step was also related to the view results step, in which, went back to the objective exam step in order to access scaffolding for knowledge support (the arrow beside the test) to obtain more information about the rubor of dependency test.

In session two, Shannon had an increase in out of order events in the third session, going from three out of order events to five out of order events. The prevalence of these out of order events in the third session were for three reasons. The first reason for the out of order events related to collecting more data in the objective examination screen after viewing results (2 occurrences) indicating a need for more tests to support her hypothesis. The second reason for the out of order event was that Shannon required hard scaffolding support (process management) for the decisional process to enable final hypothesis articulation through the integration of initial data to objective data. This assertion is supported by Shannon's viewing returned subjective and objective data, present on the view results screen and the record data screen, respectively, after reaching the final hypothesis screen. Finally, Shannon's other out of order steps were related to the need to support generation of her final hypothesis through seeking knowledge support by accessing soft scaffolds (2 occurrences) on the record data screen (about conditions). In her final session, Shannon became more organized in her process, and was in congruence to the HOAC order during the entire process.

Charlotte. Presented in Figure 6.16, below, is Charlotte's process that she followed during mobile application use over the three sessions. Within the figure, in order steps are depicted in blue, and out of order steps are depicted in orange. Following the figure, themes derived from the sequence followed by Charlotte will be presented with a description of actions and rationales for the actions to support these thematic statements.

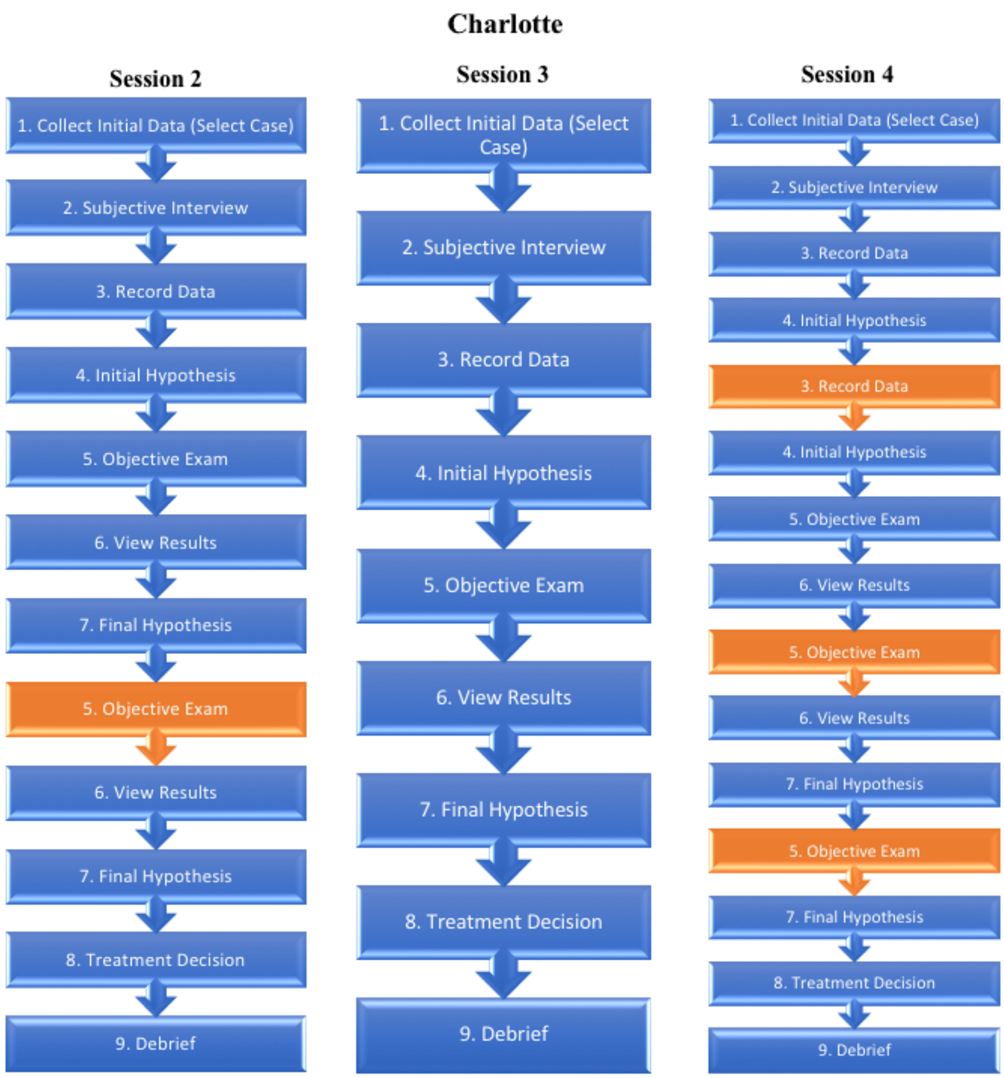


Figure 6.16. Charlotte's Order for Reasoning During Mobile Application Use.

Over the three sessions with the mobile application, Shannon had one out of order event during session two, no out of order events during session three, and three out of order events during session four. This change in order events may indicate a progression in the ability to sequence the reasoning process from sessions two to three. Further implicated by the out of order events in Charlotte's case is a congruent reason to Shannon's: a need for the application to support reasoning thorough process management or knowledge support, or for Charlotte to gain more information to assist with the diagnostic process in the objective examination or final hypothesis step. Each of the sessions will be described subsequently to present support for these assertions.

During the second session with the mobile application, Charlotte received returned information on the view results screen. She then proceeded to the next step, the final hypothesis step, in which she was asked to identify non-patient identified problems. In this step, she decided that she did not have enough information, so she went back to the objective examination screen to collect more data. During this process, she received support from soft scaffolds to inform her selection of tests and knowledge about conditions. Once she had conducted more tests, she returned to the view results tab, and then to the final hypothesis screen to establish her final hypothesis.

During the third session with the mobile application, Charlotte had no out of order events. In contrast, Charlotte had more out of order events during the fourth session, consisting of four events. During her initial hypothesis step, Charlotte returned to the record data step to re-read subjective data returned, indicating a need for process management to help shape the identification of an initial hypothesis. The next out of order event was related to getting more objective data to support her reasoning, as she went from the view results step back to the objective examination to look at previously selected tests and to select more tests to confirm her hypothesis. The final two events were related to needing sense making for knowledge support in which she went from the hypothesis step to the objective exam step and back to the final hypothesis step, once she looked up information about congestive heart failure and deep venous thrombosis in order to relate her test results to the information found in about conditions.

Across Case Findings: Order of the Reasoning Process During Application Use

Overall, there was little congruence in the number of out of order events by participant. However, there were four major congruent themes derived from the sequence utilized by student-participants while using the mobile application. These themes were:

1) Participants' progression in their ability to sequence the reasoning process.

2) A need to gather more information to assist with decision making in the steps of the process supported by hard and soft scaffolding.

3) A need for discipline specific knowledge support, as implicated by access of soft scaffolds

4) A need for application re-design based upon some out of order steps that were present in participants' video-based data.

Each of these themes will be described subsequently with their supports.

Theme 1). During mobile application use, there was some evidence that participants increased their ability to sequence the reasoning process at some point within the intervention process. For example, Charlotte demonstrated this progression from session 2 to session 3, and Kerry and Shannon both demonstrated a progression from session 3 to session 4. The rationale for the change in sequence of the events could have been due to an increasing knowledge base, or due to being more directed and focused in the collection of data, resulting in fewer out of sequence events.

Theme 2). Evidence was found in Kerry, Charlotte, and Shannon's narrative of a need to gather more information to assist with decision making in various steps of the process supported by hard and soft scaffolding. This was evident in Kerry's sequence of the process when she returned to the subjective or objective examination steps, and when Shannon and Charlotte returned to the objective information step to collect data. In all cases, these actions were either triggered by reading hard scaffolding, or prompted by the need for disciplinary knowledge support through the use of soft scaffolds, discussed subsequently.

Theme 3). Evident within all participants' sequence within the mobile application was a need for disciplinary knowledge support by use of soft scaffolds. This knowledge support was needed at various points in the reasoning process, including the objective examination step, and especially during the final hypothesis the treatment decision steps. By using these scaffolds, student-participants were able to better support conducting certain tests, making diagnostic decisions, or making treatment decisions. While the scaffolds were supportive in the majority of cases (discussed in the upcoming section on reliance on and support of soft scaffolds), the lack of access to these scaffolds on the hypothesis and treatment decision pages did cause some out of order events, as the buttons to access these scaffolds were not available on these two screens.

Theme 4). A final implication provided by the out of order steps that were present in all student participants' video data is a possible need for application re-design. The sequences present within the process that provide this implication are: 1) Participants leaving the final hypothesis step to access hard or soft scaffolding buttons in the view results step or in other steps, 2) Participants leaving the objective examination step to view process management hard scaffolding in the record data step, or by 3) Out of order steps caused by the application either not automatically saving data, or not forcing text entry into the mobile application. Because these themes were common amongst participants, figures and text representing the changes needed in the mobile application based upon participants' sequence of events followed are detailed subsequently.

Taking into consideration participants leaving the final hypothesis step to access both soft scaffolding for knowledge support and hard scaffolding for process management to gain information to support their diagnostic decisions, two recommendations for changes in application design are recommended. Since the final hypothesis page does not have the buttons that provide a link to the soft scaffolds, it is suggested that this be added to the application in order to reduce the out of order sequences present in participants' interaction with the mobile application. This means that the buttons that are located on most steps in the process that link to the soft scaffolds would be placed onto the final hypothesis page as depicted in Figure 6.17.

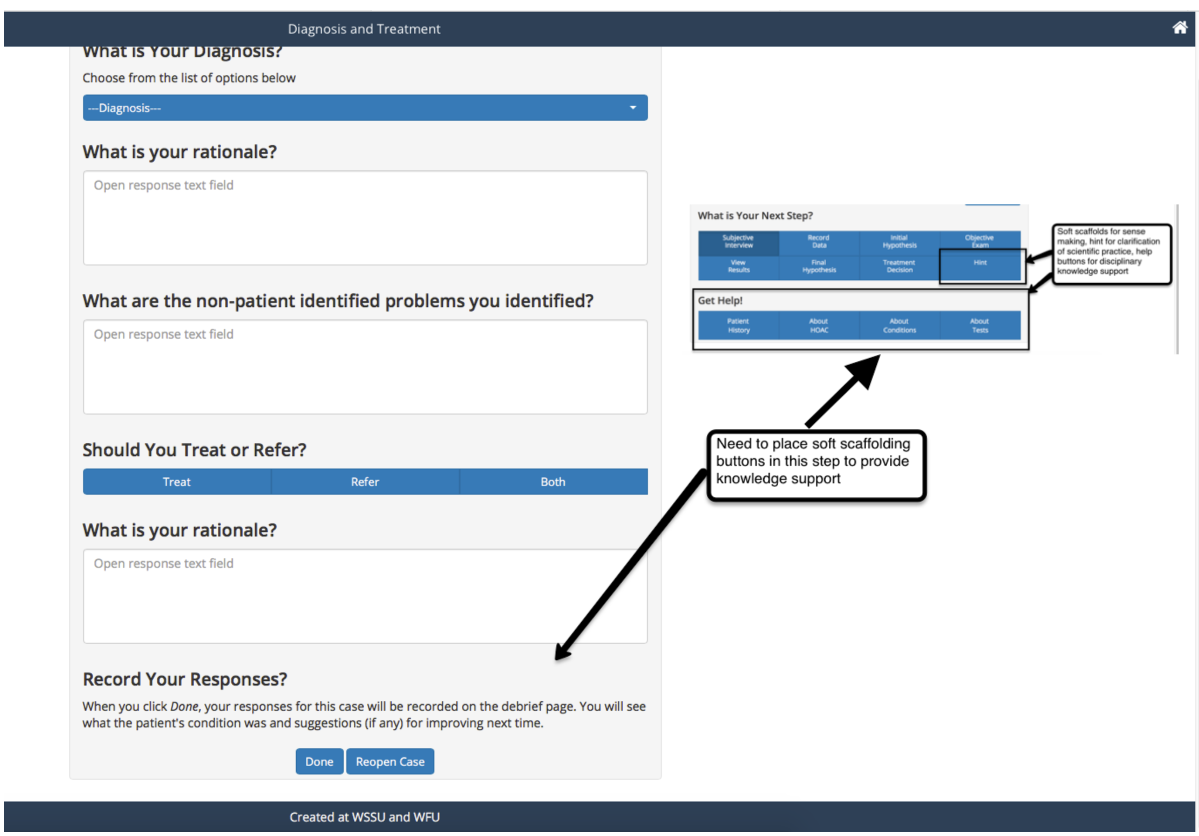


Figure 6.17. Addition of Soft Scaffold Button Links.

The other modification suggested to the final hypothesis screen is based upon the participant action of leaving final hypothesis step and returning to the record data or view results step to read process management hard scaffolding. This modification would increase the amount of data that the application returns to the participant, including subjective and objective information, during the final hypothesis step, as no information from previous steps is currently returned. Figure 6.18 depicts this modification.

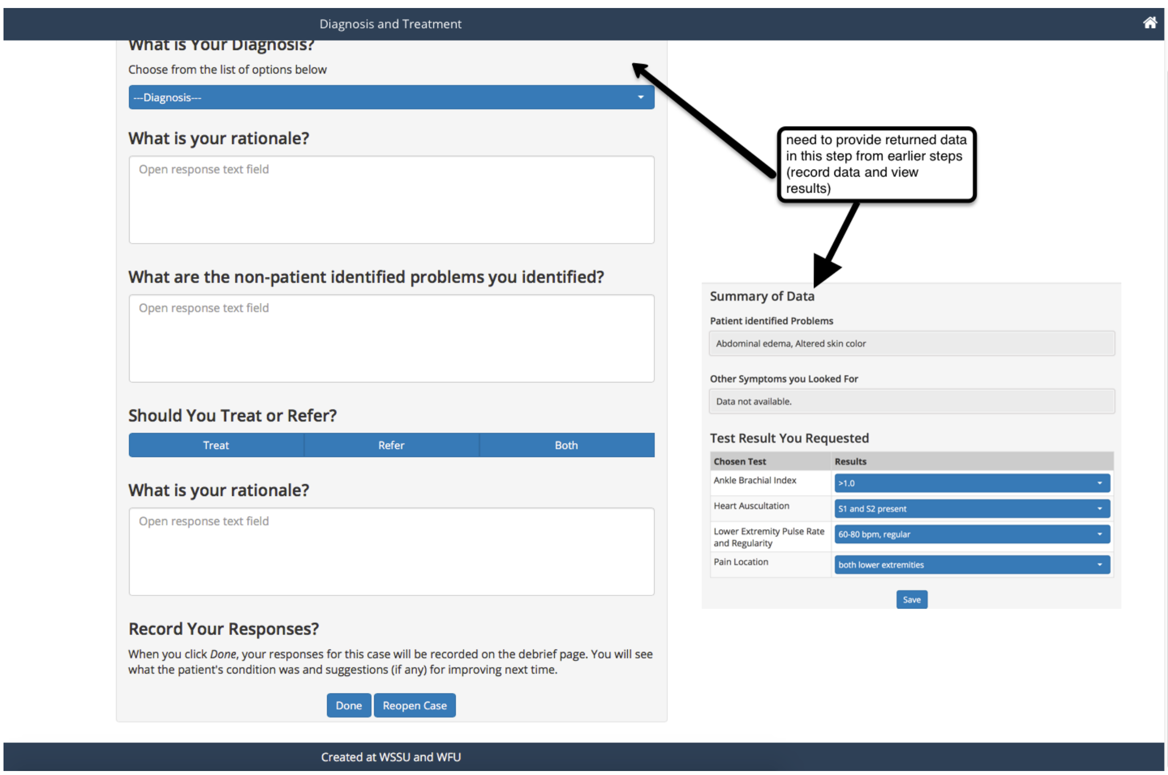


Figure 6.18. Addition of Process Management Scaffold to the Final Hypothesis Step.

Another cause of participants' out of order process while using the mobile application was due to leaving the objective examination step to view process management scaffolding in the record data step. This out of order step could have been eliminated by adding process management scaffolding to the objective examination step. This process management scaffold would therefore return two types of data to participant during the objective examination step: data from the subjective examination and data related to patient identified problems from the record data step. This modification is noted in Figure 6.19.

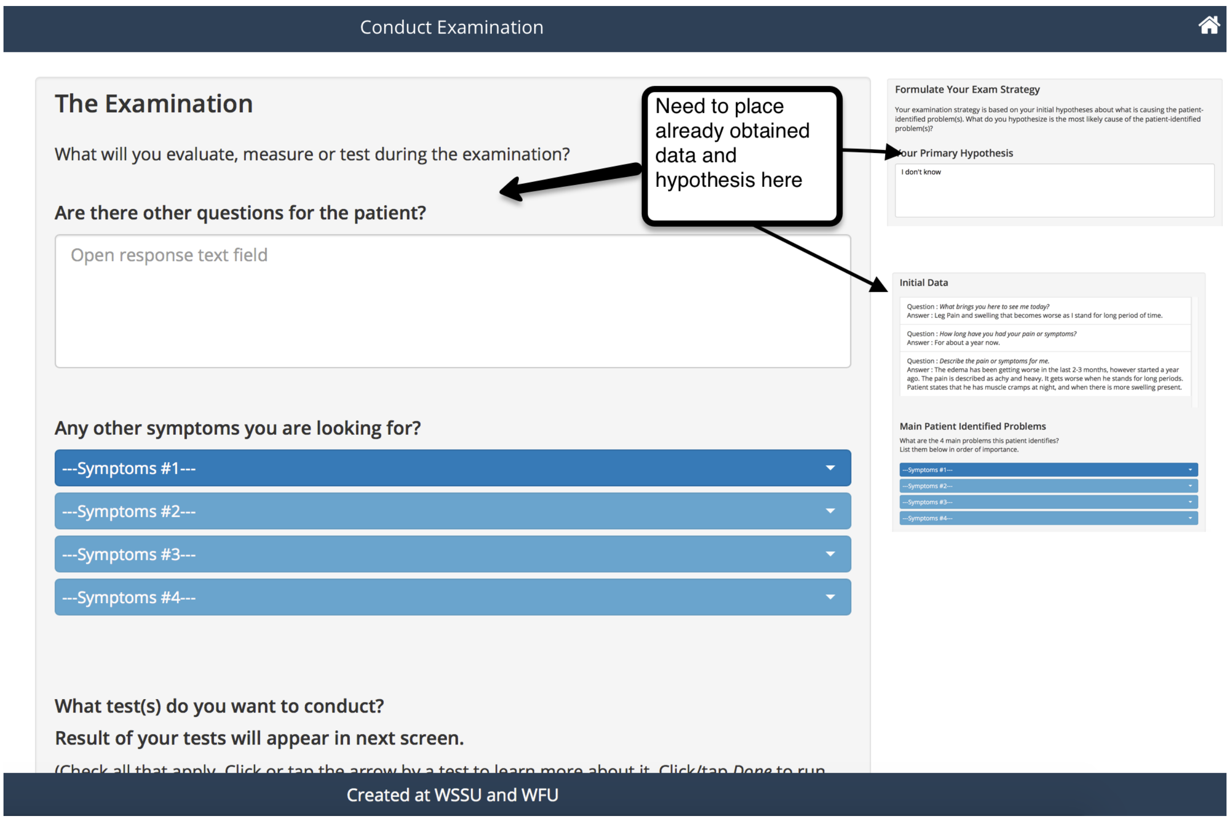


Figure 6.19. Addition of Process Management Scaffolding to the Objective Examination Step.

The final needed change to the mobile application is based upon participants' out of order steps that were either caused by the application either not automatically saving data, or not forcing text entry into the mobile application. In order to address this concern, the app should force data entry into text boxes that are essential to the reasoning process (like the initial hypothesis step) by preventing advancement to the next step in the framework. Further, the app should automatically save any data when buttons related to the steps in the HOAC-II-1 are clicked or tapped to prevent data loss. An exemplar of this recommendation is depicted in Figure 6.20, below.

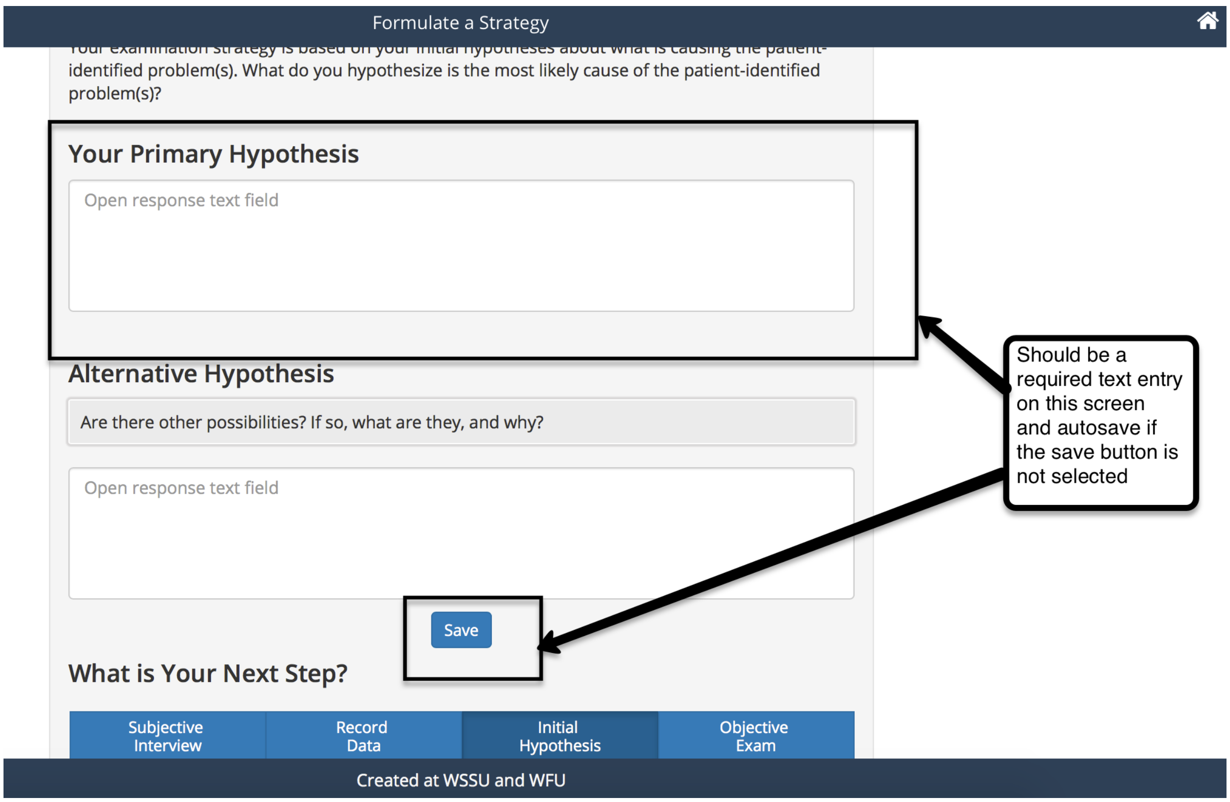


Figure 6.20. Addition of Process Management Scaffolding to the Record Data Step.

Within Case Findings: Reliance on and Support of Soft Scaffolds for the Reasoning Process

Presented within this section are the soft scaffolds utilized by student-participants over the three sessions with the mobile application. In each participant's section will be a table that outlines the type of scaffold utilized, the application step in which it was utilized, the number of times that the scaffold was utilized, and whether the scaffold was supportive in the reasoning process, with non-supportive scaffolds denoted with an asterisk. Further explained within each participant's section is how scaffolding either was supportive, or did not support the reasoning process.

Charlotte. Located within table 6.4 are the soft scaffolds utilized over sessions two, three, and four with the mobile application.

Table 6.4. Soft Scaffolds Utilized by Session by Charlotte

Application Step	Sense Making: Knowledge Support About Patient History	Sense Making: Knowledge Support About Conditions
Session 2		
Objective Exam	1*	
Record Data		1
Session 3		
Objective Exam	1	
Session 4		
Initial Hypothesis	1*	
Final Hypothesis		2

*=scaffold not supportive

Charlotte utilized two different types of soft scaffolds during her sessions with the mobile application: about conditions and about patient history. Considering the scaffold, "about conditions," there was an overall decrease from sessions two to three, and a minimal increase in the use of this soft scaffold in session four. This scaffold was coded as supportive to provide disciplinary knowledge support, in that it assisted her in informing what tests to select in the objective examination step (session two), or in providing confirmatory data for supporting her diagnostic hypothesis (session four). In observing Charlotte's use of the scaffold "about patient history" the use of this scaffold remained constant in the number of times in which it was accessed over the three sessions, however when it was accessed differed in session four. This scaffold was coded as unsupportive in sessions two and four, as it did not change her diagnostic process or her goal-oriented behavior towards selecting information in the application. However, it was coded as supportive in session three, as Charlotte stated that she used the information found in the scaffold to confirm that she did not need to return to the subjective exam step to collect more data.

Kerry. Located in Table 6.5 are the soft scaffolds utilized by Kerry over sessions two, three, and four with the mobile application.

Table 6.5. Soft Scaffolds Utilized by Session by Kerry.

Application Step	Sense Making: Knowledge Support About Conditions	Sense Making: Knowledge Support Arrow for Information About Tests	Sense Making: Knowledge Support Clarifying Scientific Practice	Sense Making: Knowledge Support About Tests
Session 2—None Used				
Session 3				
Objective Exam	2*	8*		
View Results	4*			
Final Hypothesis			2	
Session 4				
Record Data	1			1
Objective Exam		7		
Final Hypothesis			2	

*=scaffold not supportive

Kerry transitioned from not using soft scaffolds in session two, to increasing the use of soft scaffolds in session three, and decreasing usage in session four. When soft scaffolding was utilized in sessions three and four there were differences and similarities in its usage. The differences in soft scaffolding utilized during sessions three and four were related to the types of information accessed and the support received from the scaffolding, described subsequently.

During session three, Kerry utilized three different types of soft scaffolding: clarifying scientific practice, about conditions, and the arrow beside the tests. Kerry's use of the clarifying scientific practice soft scaffold was due to not entering an initial diagnostic hypothesis. Therefore, Kerry was cued twice by the soft scaffold at the end of the reasoning process (in the final hypothesis step) to go back and enter an initial diagnostic hypothesis. This scaffold was coded as supportive, in that it reminded her to ensure that she had entered data into all of the steps of the process.

Kerry's use of the about conditions and about tests arrows during the objective examination and view results steps were related to her lack of an initial diagnostic hypothesis and use of an undirected trial and error strategy to establish a final hypothesis. These scaffolds were utilized to try and find anything that could be plausible to suggest as a diagnostic hypothesis. Therefore, the use of the about conditions and the arrow beside the tests was coded as unsupportive, as these scaffolds did not result in her achieving a correct final diagnostic or treatment decision, and also did not direct her to identify an initial, testable diagnostic hypothesis to narrow the focus of her examination.

In contrast, Kerry's usage of scaffolding for knowledge support decreased in her fourth session, and continued to be related to seeking support about conditions, about tests (both the button and the arrow beside the tests), and for clarifying scientific practice. Kerry's use of support of the about conditions and about tests was related to seeking help to support knowledge about tests during the objective exam and view results steps. The use of these scaffolds was coded as supportive in that it resulted in appropriate tests being selected to confirm her correct initial and final hypothesis. In reviewing the use of soft scaffolding for clarifying scientific practice, this scaffold was supportive, in that it cued her enter all data on the final hypothesis screen.

Shannon. Table 6.6 notes the soft scaffolds utilized by Shannon in sessions two, three, and four with the mobile application.

Table 6.6. Soft Scaffolds Utilized by Session by Shannon.

Application Step	Sense Making: Knowledge Support About Conditions	Sense Making: Knowledge Support Arrow for Information About Tests	Sense Making: Knowledge Support Clarifying Scientific Practice	Sense Making: Knowledge Support About Tests
Session 2				
Initial Hypothesis	2			
Objective Exam	2	2		
Session 3				
Subjective Exam			1	
Initial Hypothesis	3			
Objective Exam	1	1		
View Results		1		
Final Hypothesis	2			
Session 4				
Record Data				1
Objective Exam	2			
View Results	1			

Shannon's use of soft scaffolds during all sessions with the mobile application were to support disciplinary knowledge support by accessing information located in the about conditions, about tests, and arrows beside the test, and for assistance with clarifying scientific practice (only in session three). The use of scaffolding by Kerry increased from session two to three and decreased in session four. In contrast to Kerry and congruent to Charlotte, Shannon utilized soft scaffolding in all three sessions.

During session two, Shannon utilized scaffolding to support generation of an initial hypothesis by accessing information about conditions, and to support knowledge about the appropriateness of tests by accessing information about conditions and about tests in the objective examination step. During session three, Shannon's use of scaffolding was similar to session two in that she utilized the about conditions scaffold to support initial hypothesis generation and the about conditions and about tests scaffold to support the collection of objective data. However, two differences were apparent from session two. First, Shannon utilized a soft scaffold related to clarifying scientific practices scaffold to assist her in the collection of subjective data, as she did not save data that she obtained until prompted. Secondly, the about conditions scaffold was utilized during both the view results and final hypothesis step to confirm the objective tests that should be positive in certain conditions and the diagnostic decision, respectively, which resulted in her obtaining a correct final hypothesis. In contrast to session three, during session four, Shannon's use of soft scaffolds was greatly reduced, and scaffolding was utilized to support the reasoning process by obtaining supportive information when she was planning to input data in the mobile application during the record data, objective examination, and view results steps.

Across Case Summary of What Soft Scaffolds Present in the Mobile Application that Physical Therapist Student-Participants Relied Upon the Most and Scaffolding's Support for Reasoning

In considering the overall use of soft scaffolds by participants, there were similarities and differences amongst student-participants over the three sessions with the mobile application.

There were three similarities noted amongst participants. The first similarity within these student-participants was the reliance upon soft scaffolding for knowledge support to support and inform the clinical reasoning process across all three sessions. This use of soft scaffolding was possibly due the fact that these participants had minimal disciplinary specific knowledge related to the process covered in the application, the objective measures used collect data to test the diagnostic hypothesis, or about the conditions covered in the application. Secondly, there was similarity in two participants was the use of the clarifying scientific practices scaffold, which assisted participants in completing the steps in the reasoning process. Finally, a noted similarity amongst all three sessions and student-participants was that the tutorial, about the trainer, hint, or about HOAC buttons that contained soft scaffolds were not accessed, possibly indicating that these particular participants did not need these scaffolds to work through the clinical cases.

Other than these three similarities, there were some differences in the: types of soft scaffolds accessed, rationale for accessing these soft scaffolds, and step in the reasoning process in which they were accessed, as previously noted within the within case sections. This difference in the use of scaffolding, however, may indicate that student-participants were using the application for one of its intended purposes, personalized learning. Table 6.7 provides information about the types of soft scaffolds utilized over the three sessions by all participants during mobile application use.

Table 6.7. Numeric Counts of Soft Scaffolds Accessed Across Sessions.

Soft scaffold	Total Number of Times Accessed Across Participants Session 2	Total Number of Times Accessed Across Participants Session 3	Total Number of Times Accessed Across Participants Session 4	Total Number of Times Accessed Across Sessions

Table 6.7. (continued).

Sense Making: About Patient History	2	1	1	4
Sense Making: About Conditions	5	20	6	31
Sense Making: Arrow Selected to Obtain Information About Tests	2	9	7	18
Sense Making: Scientific Practice	0	3	2	5
Sense Making: About Tests	0	2	2	4
Total Number of Soft scaffolds Utilized	9	35	18	62

Over the three sessions with the mobile application, the most frequently used scaffold was information about conditions (50% of instances), followed by the arrow by the tests on the objective examination screen, which provided help about the specific test (29% of instances). A noted pattern in the use of soft scaffolds is the use of fewer soft scaffolds in session two, an increase in soft scaffolds utilized in session three, and a decrease in soft scaffolds in session four, possibly indicating a growth in discipline specific knowledge related to steps in the scientific practice, about conditions, or about the tests.

Table 6.8, below, presents the steps in which the soft scaffolds were employed over the three sessions and the summative total of instances during the step. In considering the need for scaffolding support, the steps that required the most support were the objective exam step (40% of instances), followed by the view results step (24% of instances), and the final hypothesis step (18% of instances). The reason that soft scaffolds might have been utilized in these steps is that these steps demanded articulation in the form of specifying tests to test hypotheses, interpreting test results, or determining a final diagnostic hypothesis and rationale, all of which require disciplinary specific knowledge.

Table 6.8. Soft Scaffolds Utilized by Session by Mobile Application Step.

Reasoning Step	Number of Soft scaffolds Used Session 2	Number of Soft scaffolds Used in Session 3	Number of Soft scaffolds Used in Session 4	Total Number of Soft scaffolds Used by Step
Record Data	3	0	3	6
Initial Hypothesis	2	3	4	9
Objective Exam	4	12	9	25
View Results	0	14	1	15
Final Hypothesis	0	7	4	11

Overall, most soft scaffolds used during the reasoning process in all sessions across all student-participants were generally supportive (36/52 instances, 69.2%) in the reasoning process, as they resulted in the selection of appropriate tests or diagnoses for the patient problem, or entry of data into the mobile application through clarification of the scientific reasoning process. However, in two cases, Charlotte and Kerry, scaffolding was not helpful in supporting the reasoning process, as described previously.

Collective Case Findings: Corroboration of Scaffolding and Sequencing

Discussed within this section is the relationship between scaffolding utilized and the sequence of reasoning pursued during mobile application use, and the decisions made towards diagnosis and treatment, using collective case approach. The collective case approach is utilized within this section in order to best provide inferences about the order followed and scaffolding used in relationship to the correctness of the diagnostic and treatment decisions. There were four main themes derived from this corroboration: 1) Skipped steps negatively impacted the diagnostic decisions made, 2) Soft scaffolding affected the diagnostic reasoning process, 3) Soft scaffolding affected treatment decisions made, 4) Access to soft scaffolds affected the sequencing of the reasoning process.

In considering how the sequence of the process affected the diagnostic and treatment decisions, no impact of out of order steps was apparent, except when a step was skipped. An example of this is found in Kerry's third session with the mobile application, when she skipped identifying an initial hypothesis, which resulted in an incorrect diagnostic decision, and the use of a trial and error strategy, as evidenced by the out of order steps in which she collected more objective tests than she needed in order to establish a final hypothesis.

In contrast to the limited impact of multiple out of order steps, the use of soft scaffolding was greatly impactful for the diagnostic reasoning process. If soft scaffolds were used, and no steps were skipped, these soft scaffolds positively impacted the diagnostic decision made. In contrast, when soft scaffolds were not used, the diagnostic decision was negatively impacted. An example of this is found in session two, where Kerry did not utilize any soft scaffolds to support her knowledge of conditions or tests. During her reasoning task, both her initial and final hypothesis were both incorrect, and her reflection on the case was that she needed to collect more objective data and needed more knowledge to support her conclusion. In contrast, during session two, Charlotte proposed an incorrect initial hypothesis, but was able to formulate a correct final diagnostic decision by using the about conditions soft scaffolding. A further example of the influence on scaffolding for improving diagnosis is found in Shannon's third session with the application. Shannon first proposed a non-specific initial hypothesis (lack of oxygen, possibly arterial), however, after reading information about arterial insufficiency and compartment syndrome, was able to select appropriate tests and measures, and make a correct diagnostic decision (compartment syndrome).

A further influence of scaffolding was noted on the treatment decisions made by participants. Again, there was little influence on the order of the reasoning process on the ultimate outcome of the clinical decision made towards treatment. When participants obtained a correct final hypothesis, and utilized the about conditions help section, they were more likely to make a correct treatment decision. An example of this is found in session four, where all student-participants obtained a correct initial and final hypothesis, all accessed about conditions prior to making a final decision, and all decisions regarding treatment and treatment rationale were correct. In contrast, during Kerry's second session, when no scaffolding was accessed, Kerry made an incorrect decision towards treatment for her incorrect final diagnosis of compartment syndrome (to treat, instead of the appropriate decision, refer).

Finally considered is that access to soft scaffolds affected the sequence of the reasoning process. If soft scaffolding was not available to a participant on a step in which knowledge support was needed, this often caused an out of order step as previously described. Further iterations of the applications should consider this as the application is re-designed.

Conclusion: Summary of The Findings for Research Question Two

In considering how scaffolds informed the reasoning process there were several effects, which will be discussed in relationship to the literature in Chapter 7. Summarized within this section will be the sequence of the reasoning process utilized during mobile application use, the use and support of scaffolds during the reasoning process, and the articulation between scaffold use and the sequence of the reasoning process. Finally, limitations to the data analysis process will also be presented.

There were four major findings implied by the sequence used by participants during application use. These findings were that participants demonstrated a better ability to better sequence the reasoning process, that hard and soft scaffolding assisted with decision making within the steps of the process, that participants needed just-in-time, discipline specific knowledge support, and that the application needed some re-design to include more access to soft scaffolds and more process management hard scaffolds to return information to participants at decisional points.

Considering how scaffolds were supportive for the reasoning process, all student-participants employed the soft scaffolding present in the mobile application to provide just-in-time, discipline specific knowledge support, with the majority of scaffolding usage being coded as supportive for the reasoning process (60% of instances). The use of these scaffolds provided support for knowledge related to the scientific process, about objective measures, and about tests either through access of the button or the arrow beside these tests. These scaffolds were especially needed when articulation was required of the participants during steps in the process. However, in evaluating the use of these scaffolds there were some individual differences in the: types of soft scaffolds accessed, rationale for accessing these soft scaffolds, and step in the reasoning process in which they were accessed. This difference in the use of scaffolding, however, may indicate that student-participants were using the application for one of its intended purposes, personalized learning.

While three types of soft scaffolds were used and were supportive, it is possible that some scaffolds were not needed, as no selected participant utilized the tutorial, about the trainer, hint, or about HOAC buttons that contained soft scaffolds. Further research into the mobile application should evaluate the need for these scaffolds.

Considering the impact of sequence and use of scaffolds together, there were four main themes derived. These were: 1) Skipped steps negatively impacted the diagnostic decisions made, 2) Soft scaffolding affected the diagnostic reasoning process resulting in more correct diagnostic decisions, 3) Soft scaffolding affected treatment decisions made resulting in more correct treatment decisions, and 4) Access to soft scaffolds affected the sequencing of the reasoning process, in that when a soft scaffold was not easily accessible it caused an out of order step.

Another limitation is found related to the sampling strategy utilized to assess video-based data. This limitation is twofold. First, only soft scaffold use was analyzed, limiting knowledge of how hard scaffolds may have directly influenced the reasoning process. Secondly, only the most active participants were analyzed. Further analysis, therefore, may change these findings as more participant data is analyzed and more scaffolding types are included.

CHAPTER 7: DISCUSSION AND CONCLUSIONS

The purpose of this study was to explore and describe the impact of a scaffolded mobile application designed in congruence with the Hypothesis Oriented Algorithm Framework II-Part 1 (HOAC II-1) on physical therapist student participants' clinical reasoning (clinical reasoning) process. A second aim of the study was to describe what soft scaffolds present within the mobile application were relied upon most by physical therapist student participants as they were working through a case utilizing the mobile application. The following research questions were explored.

Overarching Research Question

The following question was investigated: How are PT student participants' evaluation and examination processes (related to hypothesis generation, clinical decision-making regarding treatment appropriateness, use of clinical reasoning strategies, and sequencing of scientific clinical reasoning) influenced by a mobile application that provides soft scaffolds to the HOAC II-1 clinical reasoning process?

Sub-questions Related to the Problem

Two sub-questions were explored in order to elucidate facets of the overarching research question.

Research question 1. How are PT student-participants' strategies and sequence of scientific clinical reasoning and hypothesis generation influenced by a mobile application's scaffolding of the HOAC II-1 framework?

Research Question 2. What soft scaffolds within the mobile application do PT student-participants rely upon most often to inform their scientific clinical reasoning process, and how does that reliance change over three different practice sessions?

Discussion of the Findings

Covered within this discussion are the effects of the mobile application in relationship to the literature as related to research question one. Secondly discussed will be the findings in relationship to the literature for research question two. Using findings from research questions one and two, implications for application design will be summarized and discussed through corroboration of data. Following the discussions of questions one and two and implications for application design, a summative discussion of the impact of the mobile application will be given. Finally, limitations of the research, implications for future practice, directions for future research, and conclusions will be presented.

Discussion of Findings Research Question 1

Within this section, the emergent themes regarding the effect of the mobile application in respect to research question one will be discussed. First discussed in relationship to the literature will be themes derived from *pre and post task-based interviews*. Secondly discussed in relationship to the literature will be the *post only themes* that emerged that were related to participants' statements regarding the effect of the mobile application on clinical reasoning. Finally, a summative conclusion will be made regarding the findings as they relate to research question one.

Discussion of Pre and Post Task-Based Interview Findings

This section will discuss the findings attributable to the use of the mobile application in relationship to the literature derived from the *pre- and post- intervention interviews, participant form*, and *researcher field notes*. In considering pre-and post- intervention data, five different findings related to clinical reasoning emerged from participant data. These themes were:

Finding 1) Participants used lower order reasoning strategies prior to intervention and higher order reasoning strategies after intervention.

Finding 2) Participants typically needed less scaffolding support for the reasoning process post-intervention, however some scaffolds were still needed.

Finding 3) The narrative order of the reasoning process changed from less-ordered to more ordered after the intervention, and less cues were needed for the sequence of the reasoning process.

Finding 4) There were improved clinical reasoning outcomes related to making a diagnosis post intervention. This outcome resulted from an increased ability to utilize a higher order reasoning strategy and improved sequence of the reasoning process. However, some errors persisted related to making treatment decisions.

Finding 5) Participants' perceptions of influential constructs that facilitate clinical reasoning either remained constant or changed.

Finding 1) Participants used lower order reasoning strategies prior to intervention and higher order reasoning strategies after intervention. From the initial interview to the subsequent interview, there were three changes in the reasoning strategies observed from the narrative analysis. These included an advancement in the ability to utilize higher order reasoning strategies, changes in the number of strategies utilized by each participant, and an ability to consider patient and non-patient identified problems. Each change will be discussed subsequently in relationship to the literature.

First, from the analysis, it appears that the mobile application facilitated the use of higher order reasoning strategies, which presents the first evidence for mobile technology's (MT) ability to influence and improve the types of clinical reasoning strategies utilized in physical therapist

(PT) students. This improvement is best illustrated by comparing the student-participants' initial and subsequent strategies utilized for clinical reasoning. Based upon the thematic *a priori* coding of the initial interviews, students initially utilized a combination of lower level clinical reasoning strategies which included trial and error, rule in/rule out, and following protocol. The use of these types of unsophisticated strategies in the initial interview is congruent with the literature regarding the development of clinical reasoning in physical therapy students and is also congruent with the literature on the development of scientific reasoning discourse (Gilliland, 2014; Hogan, Nastasi, & Pressley, 1999). However, subsequent to the use of the mobile application, each student-participant demonstrated the use of a more sophisticated, higher order clinical reasoning strategy within their interview processes. In considering this advancement of reasoning, most participants (5/6) demonstrated an ability to utilize clinical reasoning strategies used by expert practitioners: hypothetical deductive or pattern recognition (Gilliland, 2014), and one participant progressed from a trial and error strategy to a rule in and rule out strategy. This gain in the ability to use a higher order strategy to clinically reason may be attributable to the use of hard scaffolds for sense making (making the disciplinary strategy evident) and process management (consistent identification of the steps in the process) to support the reasoning process (Quintana et al., 2004; Sharma & Hannafin, 2007). This progression of reasoning is also congruent with Gilliland (2014) who found that students can progress in their reasoning strategies through practice and the use of reasoning frameworks, resulting in more sophisticated (higher order) strategies of clinical reasoning. Congruent also with Gilliland (2014), is the maintained use of the strategy of reasoning about pain, both pre-and post-intervention, which is also utilized at times by expert practitioners.

While most participants were able to progress to a more expert strategy, Shannon did not, instead, relying on the more novice strategy of trial and error. This lack of progression to a higher order strategy could have been related to two reasons: a need for more discipline specific knowledge support or the cognitive load imposed by the *task-based interview*. First, Shannon had a need for more extensive knowledge support during the *post task-based interview* due to her lack of remembering information that she needed related to the collection of data during the objective examination. Since both clinical reasoning and scientific reasoning and the use of more succinct reasoning strategies are supported best by having a comprehensive, domain-specific, accessible, well-organized, relevant, and accurate knowledge base, the lack of knowledge or inability to access knowledge when it was needed could have interfered with her ability to use higher order reasoning strategies (Lawson, 2004; Terry & Higgs, 1993; Zimmerman, 2005). Secondly, Shannon's lack of progression to a reasoning strategy more used by experts could have been due to a difficulty in thinking, retrieving information, and verbalizing her thought processes related to the use of a *task-based interview*. Since *task-based interviews* impose a high cognitive load, as they require participants to both think and verbalize their thought processes, they may interfere with information retrieval (Johnstone, Bottsford-Miller, & Thompson, 2006).

The second finding relates to the number of clinical reasoning strategies utilized by participants during the reasoning task. In considering these findings, 2/6 participants decreased (Sara and Bryan), 2/6 maintained (Marcus, and Kerry), and 2/6 participants increased (Shannon and Charlotte) the number of strategies utilized. First, the reduction in strategies noted that occurred in 2/6 of the participants is consistent with the literature that states that a refinement in expertise of clinical reasoning comes with more succinct, and fewer forms of strategy use (Boshuizen & Schmidt, 1992; Noll, Key, & Jensen, 2001; Patel et al., 2001; Patel et al., 2013).

Secondly, in those participants who maintained equivalent numbers of strategies, this maintenance is not incongruent to the development of expertise. Taking into account the strategies that were maintained, reasoning about patient factors and reasoning about pain, these strategies are utilized by both by expert and novice practitioners, as noted by Gilliland (2014). Finally, the increase in strategy use by 2/6 individuals could be attributable to these individuals applying their own metacognitive scaffolding to the reasoning process by applying visualization and cognitive modeling of the process (Crapo, Waisel, Wallace, & Willemain, 2000). This need for cognitive modeling during the task may have been due to the high cognitive load imposed by the *task-based interview* process, but may also allude to a developing level of expertise (Crapo et al., 2000; Johnstone et al., 2006).

A third and final finding related to the progression of clinical reasoning fostered by the mobile application is related to the consideration of patient-identified and non-patient identified problems. While each student-participant's use and development of clinical reasoning strategies was mainly congruent with Gilliland's conjectures about the development of clinical reasoning, their ability to consider patient identified and non-patient identified problems during the pre-interview session from a limited standpoint, and post-interview session using an integrative approach was in contrast to Gilliland's findings that an advancement of clinical reasoning comes with the ability to consider patient identified and non-patient identified problems during the reasoning process (Gilliland, 2014). The ability to consider these problems in both initial and subsequent sessions may be due to previous experiences with clinical reasoning that may have resulted from working in a clinical environment, their undergraduate major, or due to coursework within the PT program that discussed the importance of patient history. These experiences may have caused student-participants to initially and subsequently integrate prior experiences to inform their thought process, congruent with previous studies on clinical reasoning (Boshuizen & Schmidt, 1992; Patel et al., 2013). A further rationale for the development of the ability to integrate patient identified and non-patient identified problems into the reasoning process is a more refined knowledge base, possibly influenced by soft scaffolds located in the mobile application, that allowed student-participants to further consider problems identified by the patient in a more comprehensive manner (Lawson, 2004; Terry & Higgs, 1993; Zimmerman, 2005).

Finding 2) Participants typically needed less scaffolding support for the reasoning process post-intervention, however some scaffolds were still needed. Prior to this study, it was not known what types scaffolds, related to sense making, process management, or articulation and reflection, were needed to support the reasoning process in first year PT students during think aloud interviews, and how a mobile application might affect the reasoning process as expressed in a *pre and post intervention task-based interview*. Therefore, it is interesting to note that during their *pre-task-based interviews*, each student-participant required extensive scaffolding to support sense making (knowledge support, and sequencing of the reasoning process), and one participant, Charlotte needed support for clarifying scientific practices. The use of sense-making types of soft scaffolds for both knowledge supports and sequencing pre-intervention is consistent with the literature that states that novice practitioners and students who are developing clinical reasoning skills need to be supported with educational approaches that allow students to process data using decisional pathways or algorithmic frameworks, form hypotheses, and recall and organize knowledge (Higgs & Hunt, 1999; Terry & Higgs, 1993). Similar findings are found in research with scientific reasoning, that finds that scientific reasoning is best supported when the strategy is made explicit and when scaffolds support discipline specific knowledge (Brush & Saye, 2002).

After use of the mobile application, in congruence with each student-participant's development of clinical reasoning fostered by the mobile application was the decreased use of needed supports (soft scaffolds) from the *pre- to post-intervention interviews* for sense making related to 1) planning the examination, 2) clarifying scientific practices in one participant (Charlotte), and 3) knowledge support, in all but two participants. Because an algorithmic framework was utilized as a primary scaffold for scaffolding the process of clinical reasoning during application use, it is possible that the use of this framework helped students learn the process of clinical reasoning, and therefore transfer this to the *post task-based interview.* This conjecture is consistent with studies on algorithmic framework use for both scientific reasoning and scientific clinical reasoning that state that teaching using an algorithmic framework improves the use of the discipline specific strategy for scientific reasoning or scientific clinical reasoning (Demetriadis et al., 2008; Glaser et al., 1992; Patel et al., 2001; Rothstein et al., 2003).

A further decrease in the need for sense making scaffolds related to knowledge support was found in 4/6 participants. This decreased use of supports required in the *post task-based interview* could be attributable to the use of the mobile application in that it increased the ability for participants to organize knowledge and increase depth of knowledge. This finding is new for mobile technology within PT, however it is consistent with Patel (2013), who found that algorithmic frameworks when used with CAL increased knowledge and the ability to organize knowledge to inform hypothesis generation. A further explanation for a decrease in the need for these scaffolds could have been that participants increased in their discipline specific knowledge due to the soft scaffolds present in the application.

While most participants did improve in their need for sense making scaffolds related to knowledge support, 2/6 participants required the same (Marcus), or more (Shannon) support for discipline specific knowledge during the clinical reasoning process. This maintenance or increase for knowledge support could be due to the fact that these individuals are first year PT students and have not yet developed a large of amount of discipline specific knowledge, congruent with the literature (Boshuizen & Schmidt, 1992; Wainwright et al., 2011). An alternate reason for this need for knowledge support could also be due to the cognitive demands imposed by the think aloud task, which impeded the recall of learned information (Krahmer & Ummelen, 2004).

In spite of the decreased use of sense making cues during the reasoning process, every participant, except for Bryan and Charlotte, continued to need process management supports to summarize information or manage non-salient routine tasks, thereby mitigating cognitive load, which has been posited to improve decisional processes and decrease error (Croskerry, 2002). Therefore, the sustained use of this scaffold by the participants in this study could present an identified need for teaching methodologies to instruct students in how to better manage the information collected during the process of clinical reasoning. Alternately, an instructor could utilize a mobile application like the one under study, that returns information at key decisional points to manage cognitive load while students are learning to reason. In the case of those individuals who did not require process management scaffolds during their interview processes, this lack of use may indicate a better ability to manage the cognitive load imposed by the reasoning task, indicating developing expertise through better automation of the clinical reasoning process (Van Merriënboer & Sweller, 2010).

Finding 3) The narrative order of the reasoning process changed from less-ordered to more ordered after the intervention, and less cues were needed for the sequence of the reasoning process. Looking at the narrative organization of the clinical reasoning process, every participant's initial reasoning strategy was less focused and less organized, which is congruent with previous research (Patel et al., 2005). Subsequent to application use, it is apparent that every participant utilized a more organized process for the collection of data that required less cueing for the steps in the process. Further, every student participant was able to utilize fewer steps during the reasoning process, indicating more focus in the collection of data. These two findings give the first evidence within PT education for a mobile application's ability to affect the sequence of the reasoning process and increase the organization and focus of the reasoning process.

The changes made in the sequence and focus of the reasoning process with a decreased need for cueing in student-participants' *post- task-based interview* could have been facilitated by the hard scaffolds present in the mobile application related to sense making and process management, namely using an algorithmic framework (the HOAC-II-1) to make the disciplinary strategy for clinical reasoning evident and breaking down the task in to its component parts using ordered task decompositions (Quintana et al., 2004). Consistent with evidence from the medical literature, this finding agrees with assertions that practitioners are better able to organize knowledge when computer aided learning (CAL) employs algorithmic processes based upon the hypothetical deductive model of reasoning to structure the reasoning process (Patel et al., 2001).

Congruent research in the physical therapy literature also supports the use of hypothetical deductive frameworks to teach PT students, although these studies did not use CAL. Kenyon (2013) demonstrated that when PT educators used the HOAC II framework with PT students that it provided students with a “consistent and systematic method” for organizing evaluative processes and “ensure[d] that all aspects of the examination or intervention session were considered and carried out” (p. 419). Similar findings were also found from using the HOAC I framework to support clinical reasoning, which uses a similar structure for clinical reasoning to the HOAC II (Wessel et al., 2006). These authors found that the HOAC I model, when used with PT students on a first clinical rotation, helped students to “think about what they were doing and why they were doing it” (p. 5). The model also assisted them in “identifying omissions in their assessment, treatment, or reasoning” (p. 8). Finally, research by Gilliland (2014) found that the integration of external frameworks in PT curricula with first-year students, similar to the HOAC II, allowed them to better scaffold the reasoning process, resulting in a more organized and sequential process.

Finding 4) There were improved clinical reasoning outcomes related to making a diagnosis post intervention. This outcome resulted from an increased ability to utilize a higher order reasoning strategy and improved sequence of the reasoning process. However, some errors persisted related to making treatment decisions. From the corroboration between sequence and strategy, there were three main themes identified which provide the first evidence within PT for a mobile application’s ability to assist learners in the diagnostic process and to make a diagnostic decision. These themes were: 1). When less sophisticated, lower order reasoning strategies were used in combination with a less-organized sequence of reasoning, that diagnostic decisions were negatively affected (present pre-application use). 2). Conversely, when higher order, more sophisticated reasoning strategies were used in combination with a more organized sequence of reasoning, that diagnostic decisions were more likely to be correct (present post-application use). 3). Errors were present in the reasoning process both pre (errors in both diagnostic reasoning and in the treatment decision) and post-intervention (errors in the treatment decision). Each of these themes will be discussed in relationship to the literature.

Thinking about the first theme, pre-application use, participants utilized less sophisticated, lower order reasoning strategies in combination with a less-organized sequence of reasoning, resulting in incorrect diagnostic decisions. Further present within participants' narratives was the presence of less focus in subjective questioning, less time in the collection of initial data, less integration of patient identified problems into reasoning, and poor articulation between data collected in each step of the process to other steps in the process. This finding is concurrent both with literature related to the development of PT clinical reasoning, that cites that novices often have difficulty formulating and evaluating hypotheses and once they have gathered subjective and objective sources of information from the patient, spend less time in the collection of initial data, and use less reflection on action during the course of examination, which allows individuals to integrate and relate salient data to other data collected (Wainwright, et al., 2010; Doody & McAteer, 2002; Gilliland, 2014; Hendrick, Bond, Duncan, & Hale, 2009).

Considering the second theme, post application use, participants were able to use higher order, more sophisticated reasoning strategies in combination with a more organized sequence of reasoning, resulting in more correct initial and subsequent hypotheses. This meant, during the post think aloud interview, the influence of the mobile application is demonstrated by improved: correctness in their initial and subsequent hypothesis, more focused subjective questioning, more time spent in the collection in the initial data, and a better integration between patient-identified problems, subjective information collected, initial problems and hypothesis identified, objective tests selected, problem reconsideration, and final hypothesis generation. Each of these assertions will be discussed subsequently in relationship to the literature.

Enhancements produced from the mobile application related to both hypothesis generation and problem prioritization leading to a more correct final diagnostic decisions could be due to the hard scaffolds present in the application, resulting in development of clinical reasoning, consistent with the literature (Case, Harrison, & Roskell, 2000; Embrey et al., 1996; Gilliland, 2014). These scaffolds, provided throughout the reasoning process, focus on two areas, sense making and articulation and reflection. First, sense making was scaffolded by providing textual information in the manner of embedding expert guidance to clarify characteristics of scientific practices (Quintana et al., 2014). This scaffold was utilized for assisting the learner to perform problem prioritization and identification. Secondly, articulation and reflection for providing reminders and guidance to facilitate productive monitoring (Quintana et al., 2014) was scaffolded via text entry boxes. These boxes prompted the learner to articulate their thought processes. Summatively, these scaffolds therefore, asked the learner to prioritize problems, articulate, and then subsequently refine them, which may cause the learner to employ metacognition during the reasoning process. Consistent with the literature, the use of metacognition during the reasoning process or reflection-in-action, may have improved participants' reasoning process by allowing them to react to the uncertain features of the clinical problem, and then better integrate or change tactics, refine the articulation of problems, or reduce errors made (Croskerry, 2003; Patel et al., 2013; Tan et al., 2010; Wainwright et al., 2011).

Another explanation for the better interplay between subjective information acquired, the problems identified, and the objective examination measures identified could relate to the development of a more relative and accurate knowledge base. This enhancement in knowledge could have been produced from soft scaffolds present with the application, which were extensively relied upon by the three participants, Charlotte, Kerry, and Shannon, who were selected for video analysis during application use. These scaffolds provided sense-making through discipline-specific knowledge supports (embed expert guidance to help learners use and apply content) (Quintana, et al., 2014). This growth in knowledge is congruent with literature in PT or scientific reasoning that states that scientific clinical reasoning may be supported by gains in discipline-specific knowledge (Doody & McAteer, 2002; Edwards et al., 2004; Jensen, Shepard, Gwyer, & Hack, 1992).

Another reason for the finding that participants were able to better formulate a better relationship between the clinical reasoning strategy and sequence used post intervention could be attributable to the use of the case-based methodology within the mobile application. Support for this assertion is found in a study using case-based CAL methodology (Seif & Debora Brown, 2013). This study utilized a pre-test, post-test design to determine the effects of a sequential, clinically based case, presented through Moodle, a learning management system. Improvements from this intervention were found from pre- to post-test in the cognitive domains of seeking data, comparing and contrasting information, planning the examination strategy, and hypothesizing reasoning for problems, as well as using experience, or pattern recognition, as a form of clinical reasoning.

Reflecting upon the third identified theme, concurrent with each participant's progress in clinical reasoning from pre- to post intervention was a reduction in diagnostic errors, related to generating an initial and final hypothesis. However, no change was observed in student-participant's clinical decision to treat the patient or in the treatment strategies selected. These changes in the commission of error in hypothesis generation and in treatment decision-making will be discussed subsequently.

During every participant's initial interview, except for Shannon, errors were made in the diagnostic reasoning process, which is consistent with previous assertions in the literature that novice practitioners tend to have difficulty with evaluating hypotheses and making correct clinical decisions once they gather information from the patient (Doody & McAteer, 2002; Gilliland, 2014; Wainwright et al., 2010). Shannon's lack of error in the initial interview was due to using a rule in/rule out strategy in which she considered confirming and disconfirming data. In contrast, in the 5/6 participants who did not obtain a correct diagnosis and who made errors in reasoning did not: consider disconfirming data that ruled out initial hypotheses and final hypotheses, collect sufficient data in the *collect initial data* step of the process, and integrate data given in all steps to formulating a diagnosis or treatment plan. The commission of error in the initial interview is consistent with two types of cognitive sources of error found also within the literature: anchoring, or "the tendency to perceptually lock onto salient features in the diagnostic process, and failing to adjust this initial impression in light of later information," and confirmation bias, "the tendency to look for confirming evidence to support a diagnosis rather than look for disconfirming evidence to refute it, despite the latter often being more persuasive and definitive" (Croskerry, 2003, p. 777). In contrast, during each student-participant's post-interview session, participants were more organized in their process, using a data driven method of data collection related to the selected clinical reasoning strategy (hypothetical deductive, pattern recognition, or rule in/rule out) that was not influenced by biasing. This use of clear, unambiguous decision-making present in this session resulted in a more correct diagnosis, which is more congruent to expert practice, and could have resulted from the application structure as described above (Croskerry, 2002; Rothstein & Echternach, 1986; Wainwright et al., 2010).

While each participant was able make more precise and correct decisions related to diagnosis post-intervention, errors persisted from pre-intervention to post-intervention related to deciding if and how to treat the patient's diagnosis. This commission of error could have related to insufficient experience in making informed decisions (Wainwright et al., 2010) towards treatment and treatment interventions, as well as the lack of emphasis on the second part of the HOAC—II framework present in the mobile application that is related to intervention. Therefore, if enhancing treatment decisions or treatment intervention is a desired impact of the mobile application, development of this application should focus upon explicitly elaborating treatment strategy in order to improve reasoning about it.

Finding 5) Participants' perceptions of influential constructs that facilitate clinical reasoning either remained constant or changed. There were several major and minor themes that emerged from participant statements from pre-to-post regarding perceived influences on clinical reasoning. These themes either remained consistent, changed in their construct, or changed in the number of participants identifying with theme. These themes are impactful for understanding perceptions that student-participants have regarding how the mobile application may support clinical reasoning and provides the first evidence from students about what educational experiences are needed to support them as they are developing their abilities to clinically reason. These themes will be discussed subsequently.

Major themes that were consistent pre-to-post. Major themes that were identified that were consistent from pre to post were: 1. Previous experience is impactful for supporting the clinical reasoning process. 2. Knowledge is impactful for supporting the clinical reasoning process. 3. External factors like scope of practice, and PT role definition are involved in clinical reasoning. Each of these themes will be discussed subsequently in relationship to the literature.

Prior to mobile application use, all individuals identified with the emergent theme that previous/clinic experience is impactful for the clinical reasoning process. After mobile application use all student-participants, except for Kerry identified with the theme. This thematic statement is congruent with the clinical reasoning literature, that cites the impact of prior professional experience as influential to assisting the development of clinical reasoning (Embrey et al., 1996; Hendrick et al., 2009; Jensen et al., 1992; Wainwright et al., 2010). Therefore, if educators wish to adequately influence the clinical reasoning process, they should investigate providing concrete clinic or educational experiences that focus on clinical reasoning, or use an educational intervention like the mobile application used in this study, that provides support for the skills needed for clinical reasoning.

A second congruent and unchanging theme that emerged in all student-participants was that knowledge is impactful for the clinical reasoning process. Interestingly, participants' emphasis on this point is congruent with findings with literature on needed supports for the development of expert practice in physical therapy that cites the impact need for a patient-centered, well-organized, accessible, comprehensive, relevant, and accurate knowledge base (Jensen et al., 1992; Jensen et al., 2000; Terry & Higgs, 1993; Wainwright et al., 2010). This finding is significant, because it gives the evidence from a novice practitioner for the need for academicians to provide concrete experiences and knowledge supports (scaffolding) like those provided in the mobile application to allow full development of the cognitive components of clinical reasoning.

The third major theme that was emergent both pre- and post- application use was that external factors like scope of practice and PT role definition are involved in clinical reasoning. While not extensively studied in physical therapy, it has been suggested that learning to reason involves being contextually immersed in the context of clinical practice and includes values and beliefs of professional socialization and culture (Ajjawi & Higgs, 2008). Therefore, based upon this information, it is important for educators to find contextually significant experiences like case studies (like those used in the mobile application) or clinical practice experience that include elements of scope of practice and role definition in order to provide better context to the clinical reasoning process.

Major themes identified pre-intervention and post-intervention that changed in their construct. A theme identified pre-application use related to needing more information to support clinical reasoning changed in its construct in two ways post-application use. First, the theme changed in its thematic statement post-intervention to collecting appropriate tests and measures supports the clinical reasoning process, and secondly, by the endorsement of the statement by all student-participants. The change in this construct is significant in that it gives evidence from student-participants that the collection of information in the clinical reasoning process needs to be specific to the patient problem in order to adequately diagnose the problem. This construct is however, not significantly different from the clinical reasoning literature. First, the collection of appropriate data, with increased focus on subjective data collection, is congruent with literature on expert practice that states that experts tend to spend more time in the collection of data with the patient, develop a deep understanding of the patient case, and use these data and understandings to inform their reasoning process (Edwards et al., 2004). Further consistent with the clinical reasoning literature on expert practice in physical therapy, is the theme that collecting appropriate tests and measures supports the reasoning process (Rothstein et al., 2003). Both of these themes, therefore, have implication for PT education practice, in that students need to be explicitly taught how to collect and prioritize subjective and objective information while they are developing the capacity to clinically reason. This explicit teaching could be implemented with hard scaffolding in the classroom, or by using a tool like the mobile application under study that uses hard scaffolding that asks participants to select subjective information and prioritize problems.

Major themes emerging post-intervention. A new major theme that emerged post-intervention was that sense making (related to discipline-specific expert knowledge and knowledge of scientific practices) is necessary to support clinical reasoning. This theme is significant, because it provides the first evidence from novice practitioners that MT instructional scaffolding related to disciplinary strategies for clinical reasoning, knowledge support, hypothesis generation, and manipulation of data is important for teaching clinical reasoning. Studies within education also support this conjecture from a scientific reasoning perspective in that tools can affect how people make sense of content, manipulate data, and connect to disciplinary strategies (Anderson, Corbett, Koedinger, & Pelletier, 1995; Linn & Slotta, 2012).

Minor themes that became major themes post intervention. The emergent theme that confidence is needed to support clinical reasoning changed from a minor theme pre-intervention to a major theme post-intervention. The recognition of the importance of confidence by these student-participants, therefore, may be due to their relative inexperience, their developing knowledge and ability to clinically reason, and possibly their recognition of confidence as a quality of expertise. This conjecture is supported by the clinical reasoning literature within physical therapy, where confidence has been described as a quality of expertise that develops when a situation can be analyzed and when expert knowledge can be used to manage the condition (Hendrick et al., 2009), when individuals can interact with problems in uncertain contexts, and when effective decisions are made (Christensen, Jones, Higgs, & Edwards, 2008; Babyar et al., 2003).

Major themes identified pre-intervention that became minor themes. The theme that process management support (related to cognitive load management or keeping the process in mind) is needed for clinical reasoning changed from a major theme pre-intervention to a minor theme post-intervention. However, this theme is significant in two ways. First, it is significant in that it identifies a need for educators to teach individuals how to manage the data generated by the task and the task itself, or use a form of technology, like the mobile application under study, that provides appropriate process management scaffolding at key decisional points. Secondly, it provides the first evidence from student-participants that is consistent with the literature on scaffolding that states that learners need supports to know what is relevant, and to need assistance to handle routine tasks (Knapp & Watkins, 1994; Quintana, Eng, Carra, Wu, & Soloway, 1999).

Minor themes emerging post intervention. A minor theme that emerged post intervention is that articulation and reflection is necessary for clinical reasoning. This statement is congruent with the literature on the development of clinical reasoning and scientific reasoning, and on the development of expertise in both scientific reasoning and clinical reasoning in that the use of reflection is a sign of growing expertise (Schunn & Anderson, 1999; Wainwright et al., 2010). Therefore, educators should find ways to instruct students on how to reflect on and in action, and provide appropriate supports, like those provided in the mobile application in order to facilitate the growth of this essential skill.

Post Only Findings Discussion: Impacts of the Mobile Application

Three major themes and one minor theme emerged regarding the impact of the mobile application. These are:

1. The mobile application was impactful in three ways: structuring the process of examination related to process management and sense making related to the disciplinary strategy for problem solving, supporting gains in increased knowledge, and supporting increasing the ability to focus on and identify the problem.

2. The mobile application supported articulation and reflection.

3. The mobile application needs changes.

Minor theme emerging. A minor theme emerged from Kerry and Charlotte that the application supported repeated practice. Each of these themes will be discussed subsequently in relationship to the literature.

The first theme, that the mobile application was impactful in three ways: structuring the process of examination related to process management and sense making related to the disciplinary strategy for problem solving, supporting gains in increased knowledge, and supporting increasing the ability to focus on and identify the problem, is impactful in that it provides the first evidence within PT that a mobile application can facilitate necessary factors to support the process of scientific clinical reasoning. This thematic statement is also congruent with the literature in medicine that found that computer aided learning via a decisional support system was able to increase physicians' diagnostic performance, hypothesis generation, and clinical reasoning by providing the information and organization of knowledge needed at point of care (Friedman et al., 1999). While this application was not utilized at the point of care, this emerging theme may support its use, and therefore, further investigation is needed to see if use at the point of care supports clinical reasoning in the same way as in medicine. A second part of this theme, that the mobile application enhances problem focus, is supported by literature in medicine (Coulby et al., 2011; Luanrattana & Win, 2009), and provides the first evidence within PT that mobile technology may support individual's ability to better identify problems, which helps to better structure and focus the diagnostic process used with scientific clinical reasoning.

The second major theme to emerge, that the mobile application supported articulation and reflection, provides the first evidence within physical therapy that mobile technology may support the reflective process that informs reflection-in-action related to the articulation of clinical problems during the clinical reasoning process. Within PT education, there is limited literature related to the impact of computer-based media on encouraging reflection, however one study did assert that when students did employ blogging that they could engage in reflection on actions taken within the clinical settings (Tan, Ladyshewsky, & Gardner, 2010). However, no study was found to date that emphasizes that technology can facilitate the process of reflection-in-action within PT students.

Finally, the third major emergent theme was that the mobile application needs changes. This has implication for application re-design, and relates to the evaluation portion of the ADDIE model. Therefore, a discussion of these needed changes will be provided as an implication for practice later in the chapter.

The minor theme that the mobile application allows for repeated practice may have implications for educational practice. Since clinical reasoning is often reinforced by clinical experience, the opportunity to practice using the mobile application prior to clinic entry may allow students to develop the capability to more effectively clinically reason prior to clinical entry and therefore make them less prone to error.

Research Question Two: Reliance on Soft Scaffolds and the Impact of Scaffolds

This section will discuss in relationship to the literature the changes produced from soft scaffolding during mobile application use on the order of the reasoning process, the reliance on soft scaffolds, and the interaction between the sequence and scaffolding utilized during the reasoning process.

The Order of the Reasoning Process

Considered within this section are three major congruent themes that emerged from the sequence utilized by participants. These were: 1) Participants' progression in their ability to sequence the reasoning process, 2) A need to gather more information to assist with decision making in the steps of the process supported by hard and soft scaffolding, 3) A need for discipline specific knowledge support, as implicated by access of soft scaffolds. Each of these emergent themes will be discussed in relationship to the extant literature on scaffolding.

First considered is participants' improvements in the sequence of the reasoning process that occurred in each participant over various sessions with the mobile application. This growth in the ability to sequence the process could be due to two reasons: first, the need for soft scaffolding, which decreased over time in these participants, implying growth in knowledge, and also an improved orientation to the reasoning process. These conjectures are supported by the literature on scaffolding, which supports that as scaffolding supports an increase in disciplinary knowledge that the use of knowledge supports also decreases, and that improved orientation to disciplinary strategies from scaffolding improves the orientation to the reasoning process (Azevedo et al., 2004; Chen, Kao, Sheu, & Chiang, 2002).

The second theme derived from participant video data is that participants had a need to gather more information to assist with decision making in the steps of the process supported by hard and soft scaffolding. For the majority of participants, soft scaffolding was needed to aid and shape the reasoning process, especially as data were being collected and analyzed. Further, scaffolding positively influenced student-participant's decisions towards diagnosis and treatment. When participants sought soft scaffolding for knowledge support about conditions or about tests, or utilized the process management (hard) scaffolds, they were more likely to be correct in their initial and subsequent hypotheses. This finding is consistent with other studies that utilize sense making or process management scaffolds. A study by Brush and Saye (2002), found that process management scaffolds assisted learners in improving their outcomes when presenting the results of their inquiry, and that knowledge support helped students to consider alternative perspectives and diverse views, resulting in better reasoning outcomes, similar to those found in this study.

The final theme that emerged from the sequence of the process was that participants demonstrated a need for discipline specific knowledge support, as implicated by access of soft scaffolds. This need for sense making scaffolds to support discipline specific knowledge for clinical reasoning is congruent with literature on the development or clinical reasoning or scientific reasoning, that states that novices often need more support due to their limited knowledge of the discipline (Duschl, 2008; Glaser et al., 1992; Higgs, 1992; Higgs & Hunt, 1999; Kaufman et al., 2008; Lawson, 2004; Patel et al., 2013; Zimmerman, 2000). A further implication of the use of the scaffolds is for educators to provide just-in-time knowledge support at appropriate steps in the process, like that provided within the mobile application, in order to facilitate the steps of the scientific clinical reasoning process.

Reliance on Soft Scaffolds

The use of scaffolding and the support of scaffolds for the reasoning process is implied by all student-participants employing soft scaffolding present in the mobile application to provide just-in-time, discipline specific knowledge support, with 60% of instances coded as supportive. The use of these scaffolds provided support for knowledge related to the scientific process, about objective measures, and about tests either through access of the button or the arrow beside these tests. The use of the soft scaffolds in this manner is supported by the literature on scaffolding as outlined in scaffolding guideline one (Quintana et al., 2004), embed expert guidance to help learners use and apply science content. By incorporating the knowledge of the discipline into the mobile application, as recommended, the application was successful in aiding learners to obtain the knowledge that they needed in order to solve the clinical problem and generate a hypothesis.

In considering when scaffolds were especially needed by participants, the steps that required the most support were the objective examination step, followed by the view results step, and lastly, the final hypothesis step. A possible rationale for the use of scaffolding within these steps was the need for knowledge support to be able to interpret returned data in the view results step, or the demand for extensive articulation and reflection needed in the objective examination and final hypothesis step, which required knowledge support. This need for knowledge support during articulation and reflection may be related to the need support claims with evidence, make warranted arguments in the light of data gathered, and be able to justify their claims with the gathered evidence, which is supported by literature on scientific reasoning (Quintana, et al., 2004), and provides the first evidence within the PT profession for the support of scaffolding for the process of articulation.

Finally, there were some differences in scaffolding use across participants. This difference in the use of scaffolding, however, may indicate that student-participants were using the application for one of its intended purposes, personalized learning. This use of the mobile application in this manner is congruent with literature on m-learning that supports its use for personal, situated learning (Kukulska-Hulme & Traxler, 2005). The use of mobile technology for personalized learning this manner has implications for teaching scientific clinical reasoning in PT, in that mobile technology may increase educational equity. Equity in this context is promoted by the fact that scientific clinical reasoning is a skill that develops on a continuum, and that learners do not equally develop this skill within current educational practices. Therefore, by utilizing a mobile application like that under study, learners may employ the construct of personalized learning in order to enable them to increase practice opportunities and receive supports of their choosing for the process and knowledge needed for clinical reasoning, thereby increasing equity in learning the skills of scientific clinical reasoning.

The Impact of Sequence and Use of Scaffolding

Considering the impact of sequence and use of scaffolds together, there were four main themes derived. These were: 1) Skipped steps negatively impacted the diagnostic decisions made, 2) Soft scaffolding affected the diagnostic reasoning process resulting in more correct diagnostic decisions, 3) Soft scaffolding affected treatment decisions made resulting in more correct treatment decisions, and 4) Access to soft scaffolds affected the sequencing of the reasoning process, in that when a soft scaffold was not easily accessible it caused an out of order step. These assertions will be subsequently discussed in relationship to the literature.

When steps were skipped, in the framework both clinical reasoning towards diagnosis and treatment were adversely affected. Within physical therapy, the impact of skipping steps in the HOAC-II-1 algorithmic framework has not been studied, and therefore this is a finding that warrants further investigation to discover if skipped steps will always result in a diagnostic or treatment error.

Considered together is the impact of soft scaffolding on the diagnostic and treatment decisions made by participants. First, when soft scaffolds were utilized to support the clinical reasoning process, the clinical reasoning decision towards diagnosis was correct. A further influence of scaffolding was noted on the treatment decisions made by participants. When participants obtained a correct final hypothesis, and utilized the about conditions help section, they were more likely to make a correct treatment decision. However, when participants did not access the about conditions help section, which provided information on appropriate treatments for the conditions covered within the mobile application, they were less likely to formulate a correct treatment decision. These findings may also be explained in relationship to the literature in scientific reasoning, where soft scaffolding was able to provide access to comprehensive, domain-specific knowledge base that supported the clinical reasoning process (Lawson, 2004; Zimmerman, 2005). Further implicated by this finding is the need for educators to provide novice learners with appropriate knowledge support during appropriate steps in the process.

Finally, when soft scaffolds were not easily accessible, they affected the sequence followed by the participants, resulting in an out of order step. This finding has implications for application design that will be discussed in implications for practice, later in the chapter.

Summary of The Impact of the Mobile Application

The mobile application was impactful to all participants without respect to demographic factors and produced three main changes that provide new contributions to the literature in PT and education on the use of MT for the development of clinical reasoning. These changes include progression in clinical reasoning produced from the mobile application, demonstrated *the pre- and post- task-based interview*, the impact of the types of soft scaffolds used, the changing need for soft scaffolding during the sessions with the mobile application, perceptions of student-participants on the impact of the mobile app on clinical reasoning, and needed changes to the mobile application.

In considering clinical reasoning, this dissertation provides the first evidence for MT that employs scaffolds to the scientific clinical reasoning process in impacting PT student-participants ability to: use higher order reasoning strategies, decrease the number of soft scaffolds needed during the task based interview process, improve the sequential order of the reasoning process, streamline the reasoning process by reducing the number or steps and/or the number of the skipped steps, and improve the ability to make a diagnostic decision, due to the ability to use higher order reasoning strategies with a refined sequence of reasoning. Further new evidence is provided from participants for supports needed for clinical reasoning including: increased discipline specific knowledge, needed instructional scaffolding for process management and sense making, confidence, experience, articulation and reflection, and the collection of appropriate tests and measures. A further impact on clinical reasoning identified by participants was scope of practice and PT role definition. In spite of these changes produced by the mobile application, the mobile application did not appear to make changes in the clinical decisions made towards treatment appropriateness as expressed during the task-based interview, and therefore, future studies should focus on investigating whether scaffolding applied to treatment decisions would affect and improve this process.

Another finding of the study is the impact of scaffolding, the types of soft scaffolds used, and the changing need for soft scaffolding over the three sessions with the mobile application.

First, soft scaffolding was mostly supportive for the clinical reasoning process, especially as data were being collected and analyzed, and positively influenced student-participant's decisions towards diagnosis and treatment. When scaffolding was not utilized or steps in the process were skipped, the clinical reasoning outcome related to diagnosis and treatment was negatively affected. Therefore, this study contributes to the literature in that it provides the first evidence of the effectiveness of hypermedia scaffolding applied to PT clinical reasoning. A second important finding is that soft scaffolding related to sense making and hard scaffolding related to process management is extremely important in first-year PT students, due to their limited knowledge base and difficulty with the cognitive load management of clinical reasoning.

The third important finding of the study is related to the perceived support provided by the mobile application for the reasoning process, which contributes to the literature on scaffolding using MT and to the PT clinical reasoning literature. Student-participants identified that the mobile application was impactful in four ways: structuring the process of examination related to process management and sense making related to the disciplinary strategy for problem solving, supporting gains in increased knowledge, supporting articulation and reflection, and supporting increasing the ability to focus on and identify the problem. A minor theme that was identified was that the application allows repeated practice, which is significant in that it allows PT students to have more opportunities to practice their clinical reasoning prior to entering the clinic. This opportunity for repeated practice may benefit students in that it makes their clinical reasoning process more refined, and less prone to error.

Finally, the fourth major finding of the study relates to needed changes to the mobile application. These changes related to changing how problems were identified by including a search bar, increasing the number of cases in the application for more practice opportunities, to correct errors in the debriefing screen (did not always function properly), and to improve support for prescribing treatment. Further changes are implicated by participants' actions within the mobile application that indict the need for more process management and soft scaffolds to be inserted into the mobile application at certain steps in the process. These proposed changes have implications for application design and should be investigated further with another study in order to determine exactly what changes would be most beneficial.

Limitations

There are some limitations to this study. First, it is not known if all knowledge acquired by these student-participants during the test period was solely due to the influence of the mobile application, as these student-participants were simultaneously enrolled in PT graduate-level coursework during the study period. However, this coursework did not strongly emphasize the same information that was communicated within the mobile application. Secondly, it is not known if the student-participants in this study will continue to demonstrate the ability to utilize higher order reasoning strategies or conduct an examination using a sequential procedure like the HOAC-II-1 with other cases that they encounter. Therefore, further research should observe subsequent clinical interactions to determine if the gains in knowledge related the use of strategies and sequencing of the clinical reasoning process translate to future clinical performance.

Further limitations relate to the sample under study. Since the sample is derived from a single institution, which is public and primarily minority-attended, it is possible that the results found in these students may not apply to other students in other programs across the country, for two different reasons. First, these students may not be representative of the population of physical therapist students across the country, since most physical therapist students attend primarily non-minority institutions, and many attend private institutions. Secondly, because other programs teach clinical reasoning differently, the application may not work as well for students at other institutions that do not share similar teaching pedagogies, curricular design, or student characteristics. For these and other reasons, including that the sample size is small, generalizability to other students in other programs may be limited.

Another limitation is found related to the sampling strategy utilized to assess video-based data. This limitation is twofold. First, only the use of soft scaffolds by participants was analyzed, limiting knowledge of how hard scaffolds may have directly influenced the reasoning process. Secondly, only the most active participants were analyzed. Further analysis, therefore, may change these findings as more participant data is analyzed and more scaffolding types are included.

The final limitations arise from the use of a think-aloud protocol in the data collection process. When using this technique, it is beneficial to have a trained evaluator to administer it (Krahmer & Ummelen, 2004). In this study, the evaluator administering the protocol has utilized a think-aloud strategy when teaching in the classroom or clinic but is not formally trained in its use. Also, when thinking aloud, the thought process may be slowed or individuals may find it unnatural because it represents a departure from a preferred method of communication (Krahmer & Ummelen, 2004). In addition, the cognitive load provided by the think-aloud method, which requires student-participants to both think and verbalize their thought processes, may be difficult for student-participants to handle (Johnston et al., 2004). For these reasons, the think-aloud process may not have given a full picture of the thought processes that were occurring within the student-participant.

Implications for Practice: Application Design

Examined within this section are the recommendations for application design, that were corroborated from participants' statements regarding application design expressed in the *post task-based interview* and through participants' actions with the mobile application related to both scaffolds utilized and the sequence followed. From these two data sources, two types of recommendations are made for application design. Implications for application changes provided by participants' statements were to: explicitly scaffold the decisional process of making a treatment decision, to change how problems are selected within the mobile application, to correct database errors, and to provide more practice opportunities. Recommendations made from participant actions are to further evaluate if some soft scaffolds are needed, and to provide more soft and hard scaffolding in different parts of the application to reduce out of sequence events. Each of these will described subsequently.

Recommendations Provided by Participant Statements

The first recommendation, to explicitly scaffold information related to the process of making treatment decisions, was derived from participant statements in the post- task-based interview, due to the fact that no participant was successful in determining a correct treatment decision. Further support was provided from participant comments in which they referenced that more support was needed within the mobile application to effectively to generate a treatment decision. While information was available in the mobile application regarding appropriate treatments for each of the conditions covered within it, participants may not have attended to or accessed the information. Therefore, future iterations of the application should consider including the second part of the HOAC-II framework as a possible scaffold for the decisional processes that relate to treatment, and more explicitly provide discipline specific knowledge support for appropriate treatments for the conditions represented within the mobile application.

A second recommendation, to change how problems are selected within the mobile application, was derived from questions that were asked about needed changes to the mobile application. To select patient identified problems within the mobile application, users have to scroll through a list of symptoms. Since this list has the potential to be long, student-participants identified that it might be better to be able to search for keywords related to these symptoms, or to be able to start typing in the selector box to decrease the need to scroll through symptoms to select them. This modification is noted in Figure 7.1.

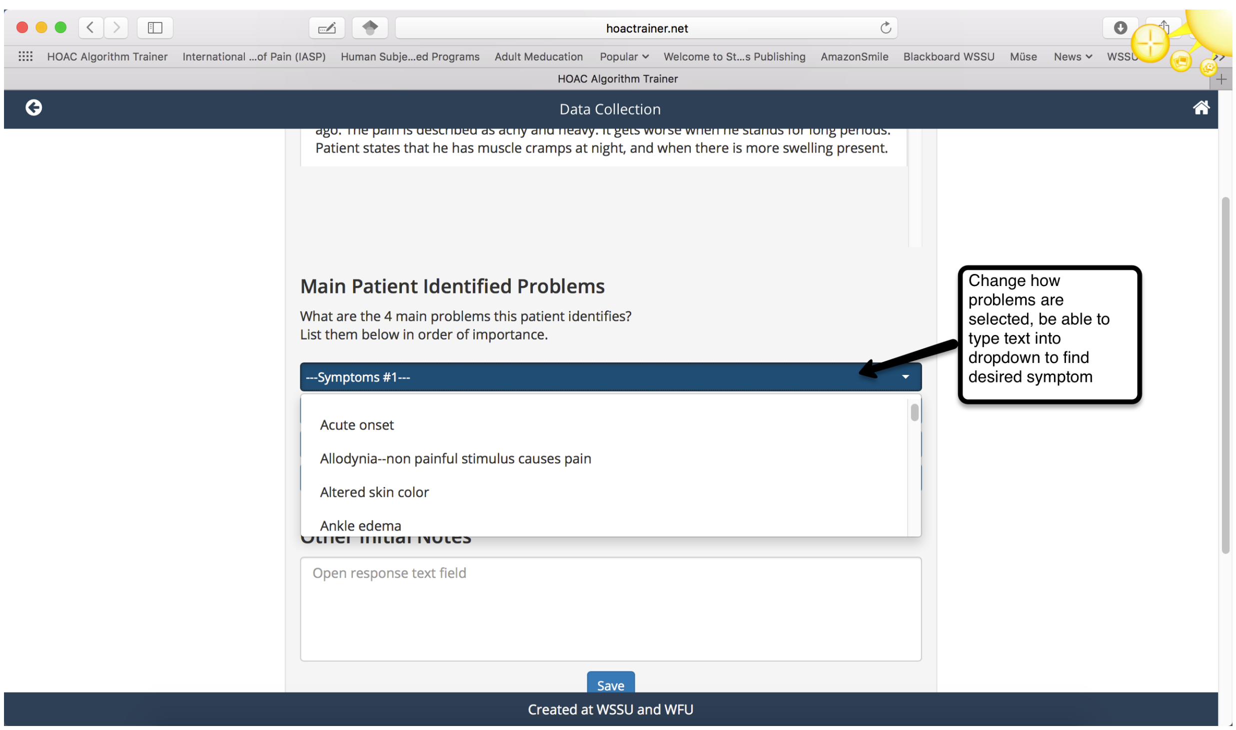


Figure 7.1. Change in How Problems are Selected.

A third recommendation was derived from participant statements and video data that referenced database errors that were present when some participants tried to access the debriefing screen. This is represented in Figure 7.2, below.

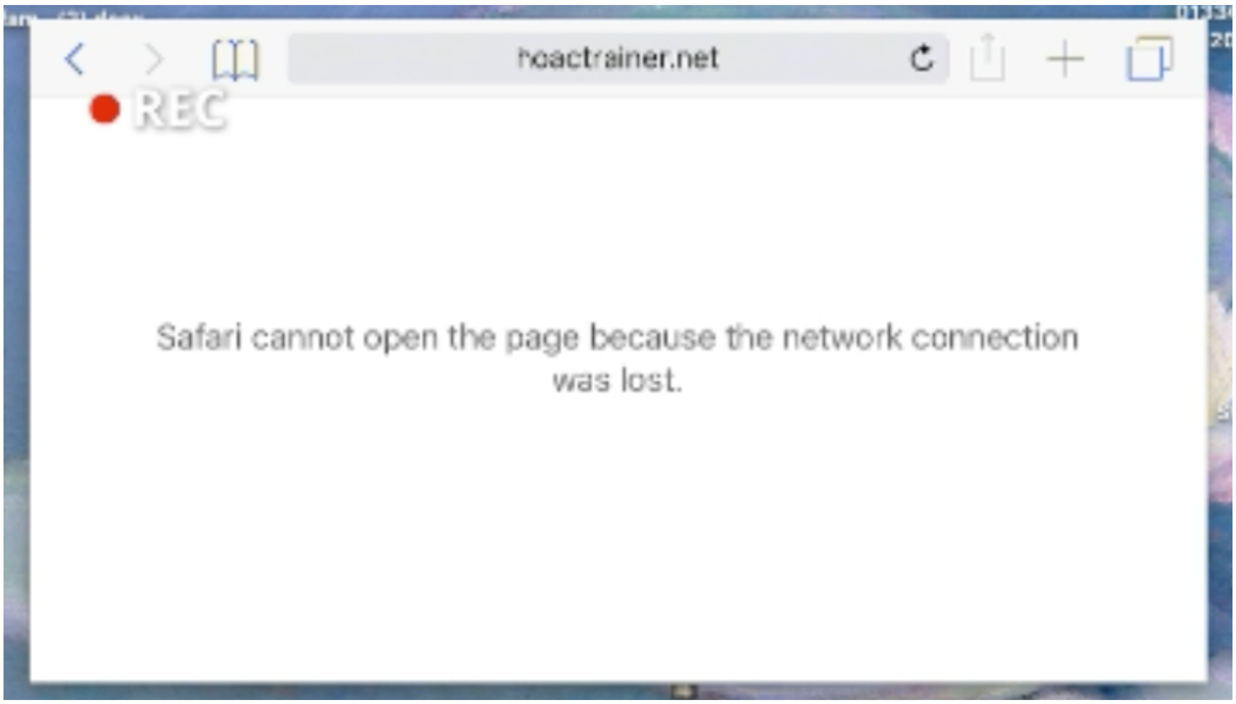


Figure 7.2. Database Error.

During the intervention phase, an attempt was made to correct this error, however, in some cases it still persisted. Future development should focus on discovering the cause for this error.

The final recommendation for future application design provided by participants' statements was to increase the number of cases provided in the application to increase practice opportunities. Since the application was already designed with administrative panels that allow the addition of more cases, it is not necessary to make an application programming modification.

Instead, it is necessary to develop more expert-reviewed cases and add these to the application to increase the learning/practice opportunities provided within the application.

Recommendations Provided by Participant Actions

During application use, no selected participant utilized the tutorial, about the trainer, hint, or about HOAC buttons that contained soft scaffolds. Therefore, it is possible that these soft scaffolds are not necessary to support learners in their reasoning process. However, since the number of participants evaluated were small (n=3), this data is not conclusive enough to recommend a change in the application. Therefore, further research into the mobile application should evaluate the need for these scaffolds.

Based upon user actions within the mobile application, it is possible that the mobile application presented obstacles to a more succinct process of reasoning. The sequences present within the process that provide this implication are: 1) Participants leaving the final hypothesis step to access hard or soft scaffolding buttons in the view results step or in other steps, 2) Participants leaving the objective examination step to view process management hard scaffolding in the record data step, or by 3) Out of order steps caused by the application either not automatically saving data, or not forcing text entry into the mobile application. Because these themes were common amongst participants, figures and text representing the changes needed in the mobile application based upon participants' sequence of events followed are detailed subsequently.

Taking into consideration participants leaving the final hypothesis step to access both soft scaffolding for knowledge support and hard scaffolding for process management to gain information to support their diagnostic decisions, two recommendations for changes in application design are recommended. Since the final hypothesis page does not have the buttons that provide a link to the soft scaffolds, it is suggested that this be added to the application in order to reduce the out of order sequences present in participants' interaction with the mobile application. This means that the buttons that are located on most steps in the process that link to the soft scaffolds would be placed onto the final hypothesis page as depicted in Figure 7.3.

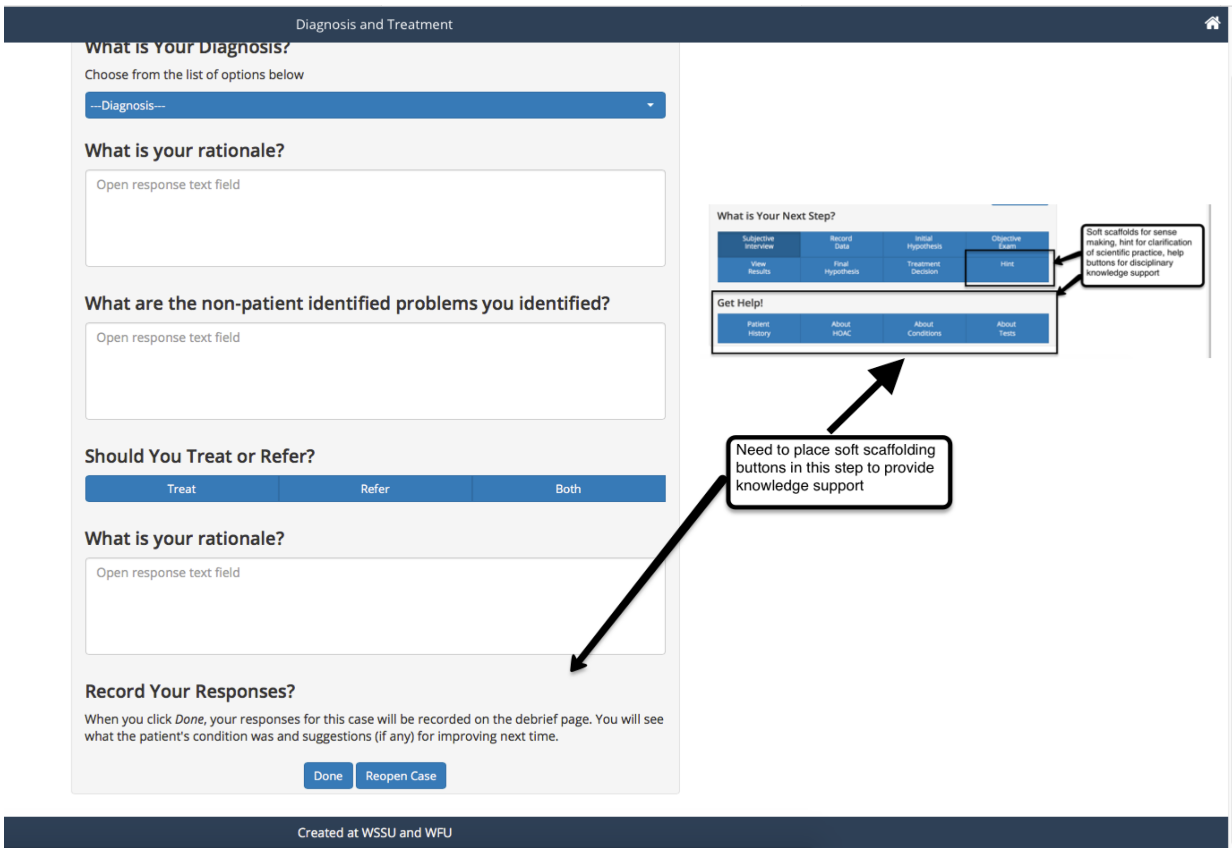


Figure 7.3. Addition of Soft Scaffold Button Links.

The other modification suggested to the final hypothesis screen is based upon the participant action of leaving final hypothesis step and returning to the record data or view results step to read process management hard scaffolding. This modification would increase the amount of data that the application returns to the participant, including subjective and objective information, during the final hypothesis step, as no information from previous steps is currently returned. Figure 7.4 depicts this modification.

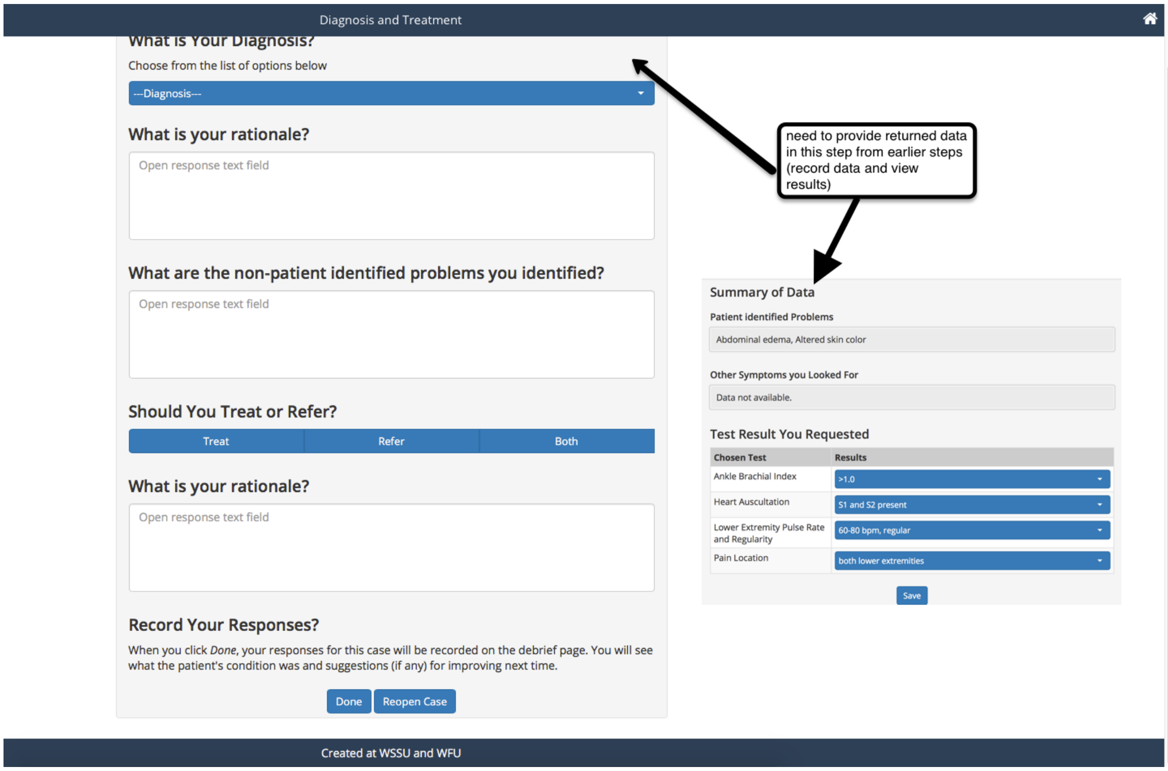


Figure 7.4. Addition of Process Management Scaffold to the Final Hypothesis Step.

Another cause of participants' out of order process while using the mobile application was due to leaving the objective examination step to view process management scaffolding in the record data step. This out of order step could have been eliminated by adding process management scaffolding to the objective examination step. This process management scaffold would therefore return two types of data to participant during the objective examination step: data from the subjective examination and data related to patient identified problems from the record data step. This modification is noted in Figure 7.5.

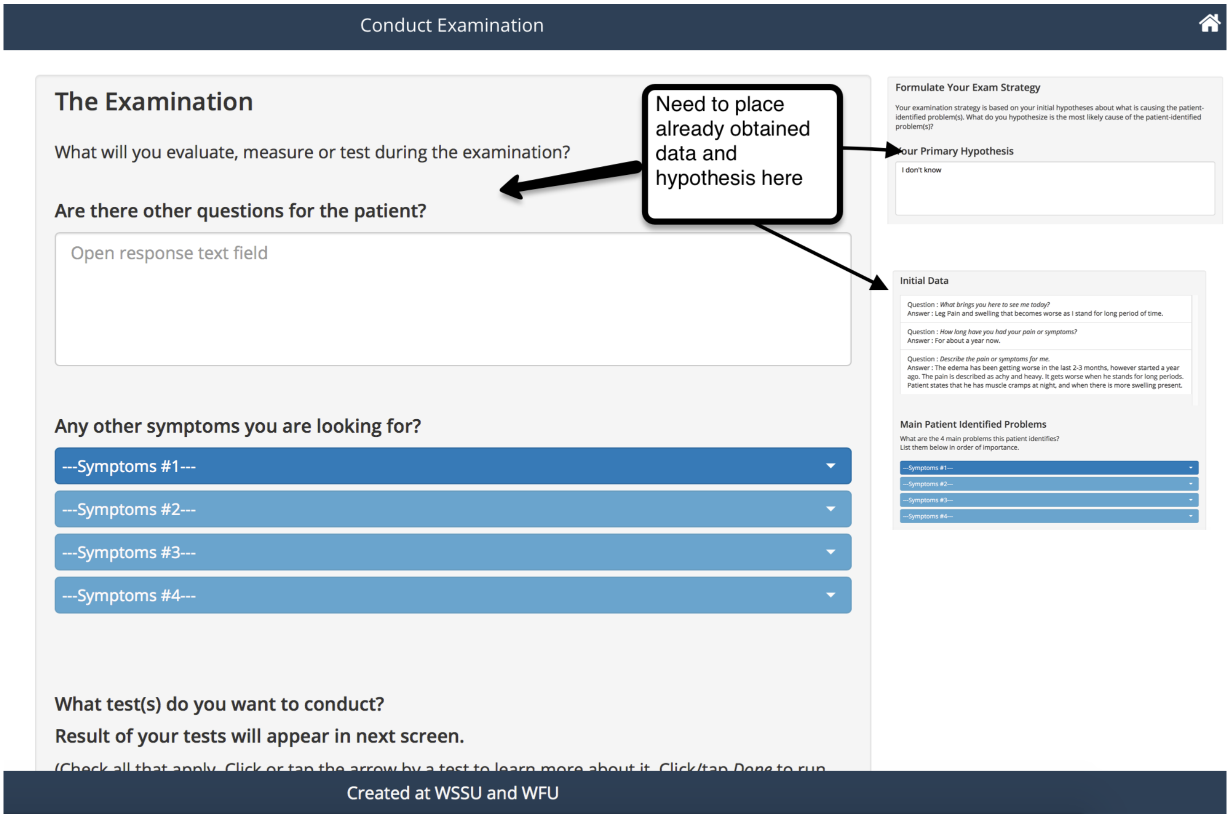


Figure 7.5. Addition of Process Management Scaffolding to the Objective Examination Step

The final needed change to the mobile application is based upon both participants' statements and participants' out of order steps that were either caused by the application either not automatically saving data, or not forcing text entry into the mobile application. In order to address this concern, the app should force data entry into text boxes that are essential to the reasoning process (like the initial hypothesis step) by preventing advancement to the next step in the framework. Further, the app should automatically save any data when buttons related to the steps in the HOAC-II-1 are clicked or tapped to prevent data loss. An exemplar of this recommendation is depicted in Figure 7.6, below.

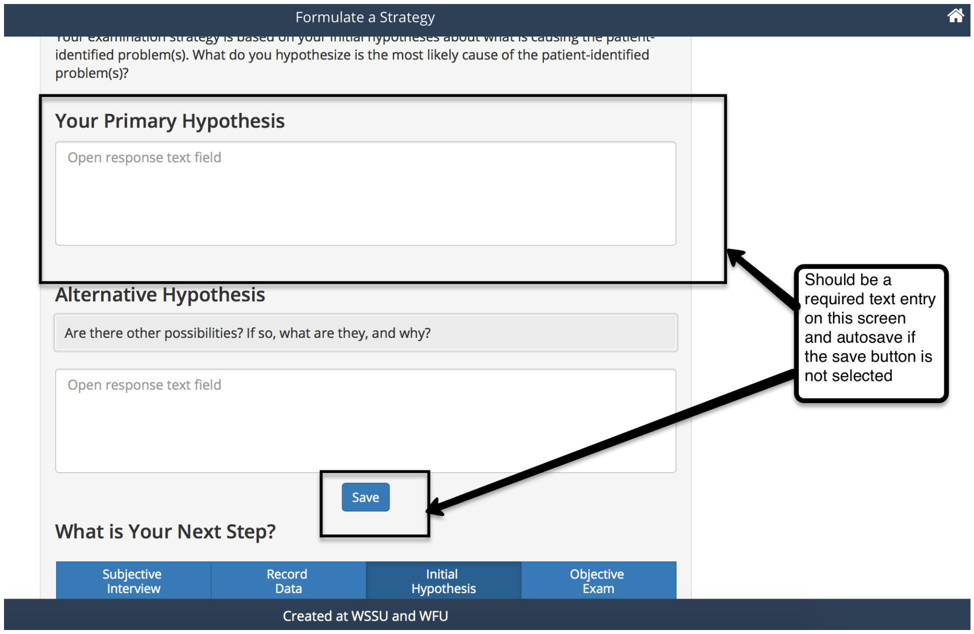


Figure 7.6. Addition of Process Management Scaffolding to the Record Data Step

Implications for Practice: Educational Approaches

The results of the study have implications for instructors who are designing hypermedia interventions to support PT clinical reasoning, educators who are supporting students in clinical reasoning, and for PT curricula. Implications from each of these perspectives will be presented subsequently.

First, this study has implications for instructional design in that interventions to facilitate PT clinical reasoning using MT. Based upon the results of the study, it is important to incorporate scaffolds to the hypothetical deductive reasoning clinical reasoning process into hypermedia to support sense making, process management, and articulation and reflection, as these factors were supportive, and were perceived to be supportive by students in facilitating clinical reasoning. Further, implicated in design is the need to scaffold case-based hypermedia that is used to teach PT clinical reasoning. Finally, the results suggest that the instructional scaffolding provided within the mobile application did not support the process of clinical reasoning towards making a treatment decision as expressed in the *post- task-based interview*. Therefore, if PT educators are wanting to support the generation of treatment decisions or patient interventions using hypermedia, a different type of framework support may need to be employed to scaffold this reasoning process.

An implication for educators who are supporting clinical reasoning development relate to the three strands of the conceptual framework employed in this study and to participant statements that relate to factors needed to support clinical reasoning development. First, it is important to note that the conceptual framework utilized within this study incorporated multiple strands including: the development of clinical reasoning, scaffolding supports for hypothetical deductive reasoning from education, and a hypothetical deductive algorithmic framework from PT. With these multiple strands of support, there was noted improvement in clinical reasoning. Therefore, if instructors want to consider how to adequately scaffold learning and evaluation and the development of hypothetical deductive clinical reasoning, implementing the conceptual framework utilized in this study may be beneficial to use in the instructional environment.

A second consideration for educators are participants' statements regarding the important factors that influence the development of clinical reasoning including: increased discipline specific knowledge, needed instructional scaffolding for process management and sense making, confidence, experience, articulation and reflection, and the collection of appropriate tests and measures. A further impact on clinical reasoning identified by participants was scope of practice and PT role definition. Therefore, educators who wish to support clinical reasoning development should consider these factors as they design interventions to support clinical reasoning, as these statements are in congruence with the extant clinical reasoning literature on the developmental process that occurs from novice to expert practice.

Finally, this study has impact to PT curricula. Often, clinical reasoning in PT curricula forms part of the implicit curriculum or may not be explicitly taught until students enter the clinic. Since students often face challenges with PT clinical reasoning upon first clinic entry, it is necessary to consider how to integrate clinical reasoning into PT curricula sooner. Based upon the results of the study, and the success of the mobile application under study, integrating this application or the framework used within the study as a technique to teach clinical reasoning with first year students, may assist in developing a stronger clinical reasoning framework for curricula.

Future Research

There are five areas of future research that should be conducted following this study to investigate the true impact of the mobile application. First, within the PT profession, no studies have been conducted to see if learning clinical reasoning strategies using mobile technology or computer aided instruction is able to transfer into the clinical environment. Therefore, it would be beneficial to discover if the gains in knowledge related to the use of clinical reasoning strategies and sequencing translate to future clinical performance, as no studies currently exist within PT on transfer of training from the use of case based scaffolded MT. However, studies using case-based approaches have demonstrated transfer of training (Huhn & Deutsch, 2011; Huhn et al., 2013). Therefore, it is necessary to investigate whether or not MT has the same effect, since the context in which it may be applied (the clinic) is different than what was previously investigated.

Secondly, no studies have been done within physical therapy that investigate how using technology to support process management during the clinical reasoning process may contribute to decreasing extraneous cognitive load. Since the mobile app returns needed information at key decisional points, it may be beneficial to conduct a comparison between the cognitive load induced by a think aloud interview and the mobile application. This investigation is necessary to see if the mobile application does indeed help students manage extraneous cognitive load (load that is not pertinent to the clinical reasoning process) and induce intrinsic and germane cognitive load that are needed for learning. These types of studies have been conducted within education, with positive results, however, this is a gap within the PT literature (Crapo et al., 2000).

Third, since clinical reasoning is a developmental process, and it is not known at what level of PT student or practitioner the mobile application would most benefit, an investigation should be conducted to see if implementing it with differing levels of PT students and residents is able to produce similar effects on clinical reasoning, since this type of investigation has not been done. In concert with this investigation, is a need to determine what steps in scientific clinical reasoning are essential to emphasize in differing levels of PT students in order to prevent diagnostic and treatment errors, as skipped steps when using the mobile application affected decisions about diagnosis and treatment.

Fourth, further analysis should be done on to include all participants' data in video data analysis that looks at the use of both hard and soft scaffolding within the mobile application to draw better inferences about which type of scaffolding had the most effects. This type of analysis would strengthen the case for the use of what types of mobile based scaffolding are truly necessary to adequately support clinical reasoning in PT students.

Fifth, and finally, since the mobile application was designed by the researcher, and a few issues were cited by participants related to design, a full design evaluation should be conducted to see if enhancements can be made in order to improve the learning process including the addition of additional scaffolding elements for sense making, process management, and explicitly scaffolding treatment decisions to improve participant's knowledge of the treatment process.

Conclusions

By using developmental andragogy that focuses on the use of instructional scaffolding with a discipline specific framework within a mobile application, it appears that PT student-student-participants are able to acquire improved abilities to perform clinical reasoning tasks, and reason more like expert practitioners. Further implied by the study is need to employ instructional scaffolding to the clinical reasoning process in hypermedia environments. This is especially important when considering how effective scaffolded MT may be in supporting the reasoning process as PT students are participating in clinical experiences. As students become better equipped to clinically reason by: using higher order reasoning strategies, being better able to identify problems, and becoming more sequential in their reasoning process, the gap between novice practitioner and expert should narrow, thereby allowing them to hopefully improve the diagnostic process and make effective decisions that are in the best interest of their patients.

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APPENDICES

Appendix A: Recruitment Script Demographic Data

Dear____________,

My name is Nancy Smith, a PhD student in the College of Education from North Carolina State University. I would like to ask you to participate in a research study that will focus on testing the effectiveness of a mobile application that will hopefully help physical therapy students learn the process of clinical reasoning and clinical decision making based upon a patient case.

You are eligible to participate in this study if you are a DPT student. As a prospective participant, your initial time commitment will be 10 minutes. If you are interested in participating, please email me at nasmith4@ncsu.edu. After sending me this email, you will be asked to sign a consent form for the collection of demographic data that also includes an agreement not to disclose the contents of the mobile application. Demographic data collected during this phase of the study will be used to select student-participants for the full study based upon information provided in order to ensure equal representation of students, and to provide aggregate data for analysis. If these data are reported in future publications or presentations, your name and contact information will not be utilized in association with any data you may provide. By volunteering for this phase of the study, you will receive access to the mobile application under study for free for a period of 6 months. Further, you may choose to enter demographic information and still not consent to be involved in the full study. Approximately 6 student-participants will be selected for the full study.

If selected for the full study, your time commitment will be approximately 8 hours, spread over approximately 3 to 6 weeks. First, you will be asked sign a consent form to participate in the full study. After consenting, you will participate in an interview prior to using the mobile application. This 1-hour interview will utilize a patient case and questioning from the researcher to seek information about your current clinical reasoning abilities. After this one-hour interview, you will be invited to participate in a 1-hour session to review application features. Following this session, you will have 3 one-hour sessions with the mobile application, where you will be asked to use the application to solve a patient case and will be videotaped using the mobile application. Following these three one-hour sessions, you will participate in a second one-hour interview that will utilize a patient case. After completion of the interview process your participation in the study will end. To protect your identity and confidentiality, pseudonyms will be utilized with any data that are reported, and protection of data will occur by using passwords and data encryption. By volunteering for this phase of the study, you will receive access to the mobile application under study for free for a period of 6 months.

If you would like to participate or have questions about the study, please email me at nasmith4@ncsu.edu, or my advisor, Kevin Oliver at koliver@ncsu.edu.

Appendix B: Informed Consent Demographic Data

COLLECTION OF DEMOGRAPHIC DATA

North Carolina State University
Institutional Review Board For The Use of Human Subjects in Research
INFORMED CONSENT FORM for RESEARCH

Title of Study Facilitation of Physical Therapy Student Hypothetical Deductive Clinical Reasoning Using a Scaffolded Mobile Application

Principal Investigator Nancy Smith, PT, DPT, GCS Faculty Sponsor (if applicable) Kevin Oliver, PhD

What are some general things you should know about research studies?

You are being asked to take part in a research study. Your participation in this study is voluntary, and you do not have consent to be a part of this research study. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. If you refuse to participate or withdraw from the study, the faculty member involved with this study will not use your refusal to participate to in any way affect: your grade in any class, the way you are treated in your courses, the department, or the university. If you feel that your academic standing has been affected by your decision to participate or your decision not to participate, please contact the IRB administrator at dapaxton@ncsu.edu or evansst@wssu.edu.

The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

What is the purpose of this study?

The full study examines the role of a mobile application in helping physical therapy students to make better clinical decisions by assisting physical therapy students to structure the sequence of clinical reasoning by employing a clinical reasoning framework. Clinical reasoning is defined as the thinking processes that physical therapist students and physical therapists perform when they are interacting with a patient and making decisions about diagnoses and the appropriateness of patient treatment. Research suggests that it is difficult for physical therapist students to learn how to clinically reason due to difficulty with organizing their thought processes. Therefore, the mobile application under study seeks to improve physical therapist students' clinical reasoning processes as they are working through a patient case. This study is significant due to the lack of research on the use of mobile technology to assist physical therapist students in learning how to structure the process of clinical reasoning. If this mobile application is found to be successful in helping student learning, it may be expanded more broadly in physical therapist education and other forms of education to help students learn clinical reasoning processes.

<u>What will happen if you take part in the study?</u>

Your time commitment for this part of the study is approximately 10 minutes.

If you agree to participate in this part of the study, you will be asked to complete a survey on Qualtrics that will ask you for your name, email address, year in physical therapy school, ethnic/racial self-identification, and gender.

Based upon data entered into the Qualtrics survey, student-participants may be asked to participate in the full study. You can consent to participate in demographic data collection, and not choose to participate in the full study. From the data collected in this part of the study, the researcher will select individuals to participate in the full study based upon certain characteristics. If selected, you will be sent an email asking you to participate in the full study. You will then have the choice to consent to participate or not participate in the full study and sign another consent form. Approximately 6 individuals will be selected for the full study.

By participating in this part of the study, you are expected to keep the mobile application and your log in confidential. You should not disclose the contents of the mobile application to any person that is not a part of the study, without permission of the researcher. If you feel you need to disclose information related to the mobile application related to your rights as a research subject, please contact the IRB administrator at dapaxton@ncsu.edu or evanssst@wssu.edu.

<u>Risks</u>

This study involves no more than minimal risk. Minimal risk is posed from exposure of demographic data entered into Qualtrics that will include your name, email address, gender identity, racial identity, year in physical therapy school, age, and cumulative GPA in physical therapy school. To protect subject confidentiality, data downloaded from Qualtrics will be kept on a password-protected computer in a password-protected file. Data that may be printed will have any identifying information removed prior to printing and will be stored in a locked filing cabinet behind a locked door. Any information that kept is on the researcher's personal computers or electronic devices will be password protected and only available to the researchers involved with the study.

To further protect subject confidentiality, survey data will be reported in the aggregate if published or presented, and names and email addresses will be removed from these data and replaced with a pseudonym. A sheet linking the participant name to the pseudonyms used will be kept in a separate document in a password-protected file on a password-protected computer. Further, GPA data will be removed and replaced with a 1 indicating Top 50% by cohort for GPA and 2 indicating Bottom 50% by cohort for GPA. Finally, the survey platform used to collect survey data, Qualtrics, is a secure platform that utilizes US based servers, US data processing, and secure socket layer transmission.

Benefits

Direct benefits: For participating in this part of this study you will receive access to the mobile application for a 6-month period of time. This may result in a direct benefit of improving your clinical reasoning processes through use of the mobile application. This may be perceived as an increase in the ability to organize information, collect pertinent data, or make better clinical decisions.

Indirect benefits: Use of the data from this part of the study may help to assist the researcher to know with which groups of individuals the mobile application is most beneficial. With this information, the researcher may be able to develop more suitable mobile applications that help physical therapy students to learn clinical reasoning skills.

Confidentiality

The information in the study records will be kept confidential to the full extent allowed by law. Overall risks to your confidentiality will be managed in multiple ways. To protect your confidentiality, any data downloaded from Qualtrics or the mobile application will be kept on a password-protected computer in a password-protected file. Data that are printed will have any identifying information removed prior to printing and will be stored in a locked filing cabinet behind a locked door. Any information that kept is on the researcher's personal computers or electronic devices will be password protected and only available to the researchers involved with the study. The researcher involved in the project will only access these data.

Further steps to protect confidentiality will be taken. First, survey data will be reported in the aggregate if published or presented, and names and email addresses will be removed from these data and replaced with a pseudonym. A sheet linking your name to the pseudonyms used will be kept in a separate document in a password-protected file on a password-protected computer. Further, GPA data will be removed and replaced with a 1 indicating Top 50% by cohort for GPA and 2 indicating Bottom 50% by cohort for GPA. Finally, the survey platform used to collect survey data, Qualtrics, is a secure platform that utilizes US based servers, US data processing, and secure socket layer transmission.

No reference will be made in oral or written reports that could link you directly to the study.

Compensation

Anyone who volunteers for this study will be offered the ability to utilize the mobile application under study for 6 months at no cost. Withdrawal from the study will not affect your ability to utilize the mobile application for this period.

What if you have questions about this study?

If you have questions at any time about the study or the procedures, you may contact the researcher, Nancy Smith, at nasmith4@ncsu.edu or 1-336-750-2198.

What if you have questions about your rights as a research participant?

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator at dapaxton@ncsu.edu or by phone at 1-919-515-4514, or Stephanie Evans, IRB coordinator at WSSU at evansst@wssu.edu.

Consent To Participate

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Subject's signature_______________________________ **Date** _________________

Investigator's signature_________________________ **Date** _________________

Appendix C: Full Study Recruitment Script

Dear _____________:

Based upon demographic information that you have provided, you have been selected to participate in the full study utilizing the mobile application. Please let me know if you wish to participate by emailing me back at nasmith4@ncsu.edu.

As a reminder, as a participant in the full study, your time commitment will be approximately 8 hours, spread over approximately 3 to 6 weeks. First, you will be asked sign a consent form to participate in the full study. After consenting, you will participate in an interview prior to using the mobile application. This 1-hour interview will utilize a patient case and questioning from the researcher to seek information about your current clinical reasoning abilities. After this one-hour interview, you will be invited to participate in a 1-hour session to review application features. Following this session, you will have 3 one-hour sessions with the mobile application, where you will be asked to use the application to solve a patient case and will be videotaped using the mobile application. Following these three one-hour sessions, you will participate in a second one-hour interview that will utilize a patient case. After completion of the interview process your participation in the study will end. To protect your identity and confidentiality, pseudonyms will be utilized with any data that are reported, and protection of data will occur by using passwords and data encryption. By volunteering for this phase of the study, you will receive access to the mobile application under study for free for a period of 6 months.

If you would like to ask questions about this study, please email me at nasmith4@ncsu.edu, or my advisor, Kevin Oliver at koliver@ncsu.edu.

Appendix D: Full Study Consent Form

FULL STUDY

North Carolina State University
Institutional Review Board For The Use of Human Subjects in Research
INFORMED CONSENT FORM for RESEARCH

Title of Study Facilitation of Physical Therapy Student Hypothetical Deductive clinical reasoning Using a Scaffolded Mobile Application

Principal Investigator Nancy Smith, PT, DPT, GCS Faculty Sponsor (if applicable) Kevin Oliver, PhD

What are some general things you should know about research studies?

You are being asked to take part in a research study. Your participation in this study is voluntary, and you do not have consent to be a part of this research study. You have the right to be a part of this study, to choose not to participate or to stop participating at any time without penalty. If you refuse to participate or withdraw from the study, the faculty member involved with this study will not use your refusal to participate to in any way affect: your grade in any class, the way you are treated in your courses, the department, or the university. If you feel that your academic standing has been affected by your decision to participate or your decision not to participate, please contact the IRB administrator at dapaxton@ncsu.edu or evansst@wssu.edu.

The purpose of research studies is to gain a better understanding of a certain topic or issue. You are not guaranteed any personal benefits from being in a study. Research studies also may pose risks to those that participate. In this consent form you will find specific details about the research in which you are being asked to participate. If you do not understand something in this form it is your right to ask the researcher for clarification or more information. A copy of this consent form will be provided to you. If at any time you have questions about your participation, do not hesitate to contact the researcher(s) named above.

What is the purpose of this study?

This study examines the role of a mobile application in helping physical therapy students to make better clinical decisions by assisting physical therapy students to structure the sequence of clinical reasoning by employing a clinical reasoning framework. clinical reasoning is defined as the thinking processes that physical therapist students and physical therapists perform when they are interacting with a patient and making decisions about diagnoses and appropriate patient treatment. Research suggests that it is difficult for physical therapist students to learn how to clinically reason due to difficulty with organizing their thought processes. Therefore, the mobile application under study seeks to improve physical therapist students' clinical reasoning processes as they are working through a patient case. This study is significant due to the lack of research on the use of mobile technology to assist physical therapist students in learning how to structure the process of clinical reasoning. If this mobile application is found to be successful in helping student learning, it may be expanded more broadly in physical therapist education and other forms of education to help students learn clinical reasoning processes.

What will happen if you take part in the study?

Your time commitment for this part of the study is approximately 8 hours spread over the course of approximately 6 weeks.

If you agree to participate in this study, you will be asked to first complete a *semi-structured task-based interview.* This interview will seek to ask questions about your thinking processes as you answer questions about a patient case. During the interview, you will be given a sheet of paper and will be asked to write any thoughts that you have regarding the case. You may also write any information that you need to write to help you in the reasoning process. This piece of paper will be collected at the end of the interview. During the interview, the researcher will provide verbal information to assist you in gaining data necessary to solve the patient problem. You may solicit information about the case by questioning the researcher. As you receive data, the researcher will ask you to describe the rationales for both the clinical reasoning strategies they are using and the hypotheses that you are generating about the patient problem. During the interview, the researcher will be documenting their impressions of clinical reasoning strategies that you are using. This interview will be audio recorded and transcribed for later analysis.

Intervention Phase

Subsequent to the *interview,* you will have four one-hour intervention sessions with the mobile application. The first intervention session will consist of an instructional session in the application's features and use.
Following the initial intervention session, consisting of instruction on the mobile application, you will proceed to utilize the application to practice your clinical reasoning using a single expert-reviewed case over three different practice sessions. The case presented during each intervention session will vary from time to time. After completion of the case you will be given feedback on your performance.
Data collected during the intervention phase will consist of things you may be asked to type into the application, such as your clinical decisions and rationales for these decisions, and by video of your interactions with the mobile application. The video data collected will have two focuses. First, a camera will be focused on you to capture your interactions with the mobile application. Secondly, video data will be collected with screencasting software using an application that allows the mobile device's display to be observed and recorded on a computer screen.

Following these four intervention sessions, you will participate in a second *semi-structured task-based interview,* following the same procedures as the initial task-based interview. After the interview is complete your participation in the study will conclude. All data will then be analyzed using qualitative and qualitative methods.

By participating in the full study, you are expected to keep the mobile application and your log in confidential. You should not disclose the contents of the mobile application to any person that is not a part of the study, without permission of the researcher. If you feel you need to disclose information related to the mobile application related to your rights as a research subject, please contact the IRB administrator at dapaxton@ncsu.edu or evansst@wssu.edu.

Risks

This study involves no more than minimal risk. You may experience stress due to participating in an interview about your clinical reasoning processes. This stress is no more than would be experienced on a day-to-day basis as a physical therapy student participating in normal clinical examinations.

You may be exposed to risk of a loss of confidentiality due to exposure of your performance on clinical reasoning tasks related to your video interactions with the mobile application. Overall risks to a loss of your confidentiality through use of video-based data will be managed in multiple ways. To protect your confidentiality, any video data will be stored on a secured password protected hard drive that will be stored in a locked file cabinet behind a locked door. Data from video interactions may be used in publication or presentation, however, you will have a right to consent or not consent to use of these data for that purpose.

Further loss of confidentiality is a risk from exposure of interactions with the researcher during the interview process via collection of audio-based data. To minimize this risk, audio data collected from the interview process will be stored on a pocket hard drive in a locked cabinet behind a locked door until they are transcribed. Transcribeme.com will transcribe audio data. Transcribeme.com uses a process to limit exposure of confidential information by: "Transcribe ME's unique micro-tasking process segments each part of your audio into small sections. As a result, each transcriber only has access to a small portion of your content in an encrypted and confidential environment. Our HIPAA-compliant service is built on the Microsoft Azure Cloud, which securely stores your information and offers best-in-class security" (http://transcribeme.com/home-en/academic-research/, retrieved March 9, 2016). Once transcribed, these data will be stored on a password-protected computer in a file. Audio data will be destroyed after transcription occurs. Data that may be printed from transcribed interview data will have any identifying information removed prior to printing and will be stored in a locked filing cabinet behind a locked door. Pseudonyms will be used during publication or presentation to protect your identity.

User data from mobile application use will be protected by several means. During user sessions with the mobile application, users will log in using a de-identified user name (their pseudonym or alternate name) and password. Data downloaded via the mobile application consisting of user data entered during application use will have only the user's pseudonym linked with it, therefore helping to protect your confidentiality. A sheet linking your name to the pseudonyms used with the mobile application or during the interview process will be kept in a separate document in a password-protected file on a password-protected computer.

Overall, confidentiality will be protected by maintaining data security and limiting access to data. To maintain data security, any data that kept is on the researcher's personal computers or electronic devices will be password protected, and only available to the researcher involved with the study, unless you consent to release of the data for publication or presentation.

A risk to you may be a real effect or perceived feeling that grades may have been affected by participation in this research project. This risk will be managed in multiple ways to ensure that your rights as a student are protected. First, you do not have to participate or consent to this research project. The decision to participate or not to participate will not affect your grades, how you are treated in courses, how you are treated in the department, or your standing with the university. You may consent to the collection of demographic data, and then not consent to this portion of the study. You may withdraw at any time from this study without penalty to a grade or class standing. If you choose to withdraw, your data will be discarded. Data will not be collected as part of a class, and there will be no course credit given for participation in the study. Furthermore, you may or may not be enrolled in a class taught by the researcher in this study and still choose to participate or not to participate. If you feel that your academic standing has been affected by your decision to participate or your decision not to participate, please contact the IRB administrator at irb-coordinator@ncsu.edu or evansst@wssu.edu.

Benefits

Direct: Possible direct benefits to you may be an improvement in clinical reasoning processes as a result of utilizing the mobile application. This may be perceived as an increase in the ability to organize information, collect pertinent data, or make better clinical decisions.

Indirect: Data collected from this study will assist researchers in knowing if this mobile application can facilitate improved clinical reasoning processes in physical therapy students. This could be of benefit to other physical therapy students or students in other medical disciplines to allow students to be more supported in generating hypotheses from collected data in order to make an appropriate decision.

Confidentiality

The information in the study records will be kept confidential to the full extent allowed by law. Overall risks to a loss of your confidentiality through use of video-based data will be managed in multiple ways. To protect your confidentiality, any video data obtained will be stored on a secured password protected hard drive that will be stored in a locked file cabinet behind a locked door. Data from interactions with the mobile application will be transcribed by the researcher and described as interactions with mobile scaffolds and will be labeled with a pseudonym instead of your name. Once transcribed, these data will be stored on a password-protected computer in a file. Data from video interactions may be used in publication or presentation, however, you will have a right to separately consent or not consent to use of these data for that purpose. If video data are used for publication or presentation, you will be identifiable by your face and by a pseudonym.

To minimize the risk of loss of confidentiality from collection of audio data collected from the interview process, these data will be stored on a pocket hard drive in a locked cabinet behind a locked door until they are transcribed. Transcribeme.com will transcribe audio data. Transcribeme.com uses a process to limit exposure of confidential information by: "TranscribeMe's unique micro-tasking process segments each part of your audio into small sections. As a result, each transcriber only has access to a small portion of your content in an encrypted and confidential environment. Our HIPAA-compliant service is built on the Microsoft Azure Cloud, which securely stores your information and offers best-in-class security" (http://transcribeme.com/home-en/academic-research/, retrieved March 9, 2016). Once transcribed, these data will be stored on a password-protected computer in a file. Audio data will be destroyed after transcription occurs. Data that may be printed from transcribed interview data will have any identifying information removed prior to printing and will be stored in a locked filing cabinet behind a locked door. Pseudonyms will be used during publication or presentation to protect your identity.

User data from mobile application use will be protected by several means. During user sessions with the mobile application, users will log in using a de-identified user name (their pseudonym or alternate name) and password. Data downloaded via the mobile application consisting of user data entered during application use will have only the user's pseudonym linked with it, therefore helping to protect your confidentiality. A sheet linking your name to the pseudonyms used with the mobile application or during the interview process will be kept in a separate document in a password-protected file on a password-protected computer.

Overall confidentiality will be protected by maintaining data security and limiting access to data. To maintain data security, any data that kept is on the researcher's personal computers or electronic devices will be password protected, and only available to the researcher involved with the study, unless you consent to release of the data for publication or presentation.

Compensation

Anyone who volunteers for this study will be offered the ability to utilize the mobile application under study for 6 months at no cost. Withdrawal from the study will not affect your ability to utilize the mobile application for this period.

<u>What if you have questions about this study?</u>

If you have questions at any time about the study or the procedures, you may contact the researcher, <u>Nancy Smith</u>, at nasmith4@ncsu.edu or 1-336-750-2198.

<u>What if you have questions about your rights as a research participant?</u>

If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Deb Paxton, Regulatory Compliance Administrator at dapaxton@ncsu.edu or by phone at 1-919-515-4514.

<u>Consent to be Videotaped During the Study and for the Use of Video Based Data for Publication or Presentation</u>

This section allows you to consent to be videotaped during the study, and to consent for these data to be used in publication or presentation. You **do** have to consent to the use of videotaping to participate in the study; however, you **do not** have to consent to the release of these data for the researcher's use in in publication or presentation. Please initial below regarding your decision regarding your consent to be videotaped and for the researcher's use of video-based data for publication or presentation. You may change your decision at any time without penalty.

Please initial your choice below.

_____I **<u>do</u>** consent to be videotaped and my video-based data **<u>may</u>** be used in publication or presentation.

_____I **<u>do</u>** consent to be videotaped, however, my video-based data **<u>may not</u>** be used in publication or presentation.

Consent To Participate

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may choose not to participate or to stop participating at any time without penalty or loss of benefits to which I am otherwise entitled."

Subject's signature_________________________________ Date _________________
Investigator's signature_____________________________ Date _________________

Appendix E: Pre and Post Task Based Interview (Adapted from Gilliland, 2014)

Researcher: I have given you a sheet of paper to write on as we talk through this case. Please use it to write notes to help you stay on track with your thought process. Please write down information that you feel is significant or will help you as we discuss the case. Please feel free to ask questions as we talk. Keep in mind as we talk about this case, I am interested in your decisions and thought processes. I am not concerned that you come up with a right answer; in fact, there are no right or wrong answers. I am just interested in your thinking and your decision-making processes.
Case Description:
(Read to participant at start of think aloud) You are working in an outpatient clinic. A new patient comes in for an initial evaluation. Before you see the patient, you have the following information about the patient: Dorothy is a 60-year-old female who has lower extremity pain that becomes worse as she walks long distances, limiting her ability to go shopping at Wal-Mart. She cannot associate the pain with any particular cause. The patient is coming in direct access for PT.
Case data to answer student questions during the stimulated recall:
Subjective:
Personal history: lives alone, works as a receptionist, sedentary, likes to crochet, exercise is limited by pain when she walks, has been getting worse in last 2-3 months
Past Medical History: She has a history of a myocardial infarction, diabetes, and hyperlipidemia.
Medications: Labetalol, Glucophage, Lipitor
Pain description: Pain is relieved by rest and worsens when her legs are elevated. Pain worsens with exercise, pain cramping, aching; 8/10 with activity; 0/10 with rest; pain in the calf, and does not affect sleep
Past treatment: limits activity when pain bothers her, direct access to the clinic
Objective:
Observation: Skin color: pale, toes are blue; presents with loss of hair and atrophy of the calf musculature; No edema present in lower extremities, no wounds
Palpation: negative
Neurological: Diminished sensation to light touch and deep pressure bilateral lower extremities
Special tests: positive rubor of dependency test
Negative orthopedic special tests
ABI .72 bilaterally
Negative venous tests
Vital signs: within normal limits
Claudication time 2 minutes to onset (100 feet)
Bicycle test positive
ROM: PROM and AROM 0 degrees DF bilaterally,
Strength: 3+/5 dorsiflexors/plantarflexors, all others 5/5

Questions to ask during the stimulated recall interview

8. Describe the initial information that you would collect from the patient. Tell me what you would think about.

   a. What information do you want to know?
9. Thinking about the information you collected, how did you decide what questions to ask the patient?
   a. What would you do with the information you collect?
   b. What patient problems have you identified? What are your initial hypotheses based upon the questions you have asked?
   c. How do you decide what tests are appropriate to perform?
10. Now, tell me about what information you would collect from your objective examination?
    a. Be specific about what you would want to test.
       i. Based upon these results, what other things would you want to test?
       ii. Describe the steps you would take in detail
    b. Thinking about the tests you chose, why did you feel that these tests were appropriate? What helped you decide to perform the tests that you chose?
11. Tell me about what you are thinking about what is wrong with the patient.
    a. With the data you have gathered, tell me about the problem list that you have generated.
       i. What tests helped you to determine that the patient had these problems?
       ii. What tests were not effective in helping you determine the patient problem or develop a hypothesis?
    b. What problems have you identified that could lead to diminished health status?
12. What diagnosis seems likely?
    a. How did you draw conclusions about the diagnosis?
    b. How are you sure that you have obtained the correct diagnosis?
13. After determining your diagnosis, what is your next step? ((Cue: Developing goals)
14. Should PT be provided to this patient?
    a. How do you make decisions about whether it is appropriate to treat a patient or not? What factors do you consider? How are you sure that you have made the correct decision?
    b. What treatment is appropriate in this case? How are you deciding what is appropriate?
    c. Why is treatment appropriate or not appropriate in this case?
15. Based upon this case, what things do you feel like you need to improve/change in your evaluation process?
16. Based upon this case, what things do you feel like you need to improve/change in your decision-making process?
17. What factors influence your thinking about generating a patient diagnosis?
    a. How did previous experiences outside of PT school affect this thinking?
    b. How have PT lecture experiences affected this thinking?
    c. How have PT laboratory experiences affected this thinking?
    d. How have instructors influenced this thinking?
    e. (Post question) How did the mobile application influence this thinking?
    f. What other factors have influenced this thinking that I have not mentioned?
18. What factors influence your thinking about making a clinical decision about whether it is appropriate to treat the patient or not to treat the patient?
    a. How did previous experiences outside of PT school affect this thinking?

b. How have PT lecture experiences affected this thinking?
c. How have PT laboratory experiences affected this thinking?
d. How have instructors influenced this thinking?
e. (Post question) How did the mobile application influence this thinking?
f. What other factors have influenced this thinking that I have not mentioned?

If you have further thoughts that you want to tell me later, please contact me at smithna@wssu.edu.

Appendix F: Participant Form

You are working in an outpatient clinic. A new patient comes in for an initial evaluation. Before you see the patient, you have the following information about the patient: Dorothy is a 60-year-old female who has lower extremity pain that becomes worse as she walks long distances, limiting her ability to go shopping at Wal-Mart. She cannot associate the pain with any particular cause. The patient is coming in direct access for PT.

Appendix G: Field Notes Protocol for Interview

Researcher:
Take notes on impressions of mannerisms/body language expressed while in interview.
Take notes about what was said during the interview.
Take notes about impressions of emotional responses during interview.
Collect student work at end of interview

Appendix H: Table A.1 Purpose of the Questions in the Task-Based Interview Process and Relationship to the Framework.

Table A.1. Purpose of the Questions in the Task-Based Interview Process and Relationship to the Framework.

Question	Purpose	Connection to Framework
Describe the initial information that you would collect from the patient. Tell me what you would think about. What information do you want to know?	Have the student-participant to elicit information about the patient case. Have the student-participant identify the problems identified by the patient.	HOAC 2 collecting initial data from referral information, the medical record and from the interview (Rothstein, Echternach, & Riddle, 2003)
Thinking about the information you collected, how did you decide what questions to ask the patient? What would you do with the information you collect? What patient problems have you identified? What are your initial hypotheses based upon the questions you have asked? How do you decide what tests are appropriate to perform?	Have the student-participant identify the problems identified by the patient. Determine how the student-participant would use the information collected from the initial subjective interview of the patient in relationship to their clinical reasoning or in alignment with the HOAC 2 framework.	HOAC 2: a and b Generating patient identified problems list, formulating an evaluation strategy, generating initial hypotheses c. clinical reasoning: elicit the strategy the student-participant is using

Table A.1. (continued).

Now, tell me about what information you would collect from your objective examination? Be specific about what you would want to test. Based upon these results, what other things would you want to test? Describe the steps you would take in detail Thinking about the tests you chose, why did you feel that these tests were appropriate? What helped you decide to perform the tests that you chose?	Have the student-participant elicit further objective data needed to reason through the clinical case. Determine alignment with established clinical reasoning strategies or HOAC framework.	3. Allow the student-participant to have more data pertinent to the clinical case. a. HOAC 2: Determine how the initial data shapes student-participant's generation of the patient identified problems and formulate and evaluation strategy. b. Determine how the objective evaluation strategy demonstrates clinical reasoning or alignment with the HOAC 2 framework.
Tell me about what you are thinking about what is wrong with the patient. With the data you have gathered, tell me about the problem list that you have generated. What tests helped you to determine that the patient had these problems? What tests were not effective in helping you determine the patient problem or develop a hypothesis? What problems have you identified that could lead to diminished health status?	Have the student-participant add non-patient identified problems to the problem list. Allow the student-participant to refine hypotheses and ask for more tests that may help them confirm/deny hypotheses.	Elicit clinical reasoning strategy or hypotheses identified. a. Allow the student-participant to collect these data identified and form a patient and non-patient identified problem list. i. and ii. identify the clinical reasoning used to formulate the evaluative strategy. Determine alignment with the HOAC 2 conduct the examination, analyze data, refine hypotheses, and carry out additional exam procedures to confirm or deny hypotheses. b. Determine if student-participant-participants are reasoning through the HOAC 2 steps of: Identify the rationale for why the problem exists or why problems will occur if no treatment is given.

Table A.1. (continued).

What diagnosis seems likely? How did you draw conclusions about the diagnosis? How are you sure that you have obtained the correct diagnosis?	Allow the participant to state the final hypothesis generated towards the problem list and diagnosis.	3. Determine if student-participants have participated in the step of hypothesis generation of a diagnosis of impairment and refining the problem list. a. and b. Determine alignment with the HOAC model and determine what clinical reasoning strategies students are undertaking.
After determining your diagnosis, what is your next step? ((Cue: Developing goals)	Allow student-participants to develop goals based upon problems identified.	7. Determine if students are aligning with the HOAC framework of establishing goals for the patient problems identified.
Based upon this case, what things do you feel like you need to improve/change in your evaluation process?	Have the participant reflect on what else they need to learn about the evaluation process.	Determine if the participant identifies different parts of the HOAC 2 framework that they omitted, or if they would use different strategies for clinical reasoning the next time.
Based upon this case, what things do you feel like you need to improve/change in your decision-making process?	Have the participant reflect on what else they need to learn about the clinical reasoning process.	Determine if the participant identifies different parts of the HOAC 2 framework that they omitted, or if they would use different strategies for clinical reasoning the next time.

Table A.1. (continued).

What factors influence your thinking about generating a patient diagnosis? How did previous experiences outside of PT school affect this thinking? How have PT lecture experiences affected this thinking? How have PT laboratory experiences affected this thinking? How have instructors influenced this thinking? (Post question) How did the mobile application influence this thinking? What other factors have influenced this thinking that I have not mentioned?	Have the participant state possible influences on their diagnostic process.	Determine what factors are most influential in clinical reasoning or in assisting them in aligning with the HOAC 2 framework. Determine if there are other factors outside of the theoretical/conceptual framework that student-participants identify as necessary for the diagnostic process.
What factors influence your thinking about making a clinical decision about whether it is appropriate to treat the patient or not to treat the patient? How did previous experiences outside of PT school affect this thinking? How have PT lecture experiences affected this thinking? How have PT laboratory experiences affected this thinking? How have instructors influenced this thinking? (Post question) How did the mobile application influence this thinking? What other factors have influenced this thinking that I have not mentioned?	Have the participant state possible influences on their clinical reasoning process.	Determine what factors are most influential in clinical reasoning or in assisting them in aligning with the HOAC 2 framework. Determine if there are other factors outside of the theoretical framework that student-participants identify as necessary for the clinical reasoning process.
What did you like about the mobile application? (open ended)	Determine user satisfaction with the application.	User satisfaction may correlate to successful learning. Will be asked at post interview only.

Table A.1. (continued).

What did you dislike about the mobile application? (open ended)	Determine user satisfaction with the application.	User satisfaction may correlate to successful learning. Will be asked at post interview only.

Appendix I: Observation Protocol

1. Student-participants will be given the application to explore for 15 minutes at the beginning of initial session to explore and understand the features of the application. Their actions will be captured using video focused in on the participant and through screen capture or screencast from the mobile device.
2. The problem (case) will be presented with the application, Students will be asked to read the patient case and enter the information into the mobile application.
3. The participant’s interactions will be captured using video on the computer screen to determine how they are accessing the information within the application.
4. Student-participants will be given a sheet of paper to write on if they need to write down something while interacting with the case or the technology tool.
5. Participant’s interactions with the mobile tool will be videotaped to determine where they are pointing, clicking/tapping, and for body language. Two sources will be used: a video camera focused in on the participant, and through screen capture on the mobile device.
6. Student-participants will be given different patient cases per session interaction of varying levels of difficulty (basic or advanced). There will be a total of 3 practice sessions in which the observational protocol is utilized

Appendix J: Table A.2. The *a priori* Coding Manual and Relationship to the Framework.

Table A.2. The *a priori* Coding Manual and Relationship to the Framework.		
Code	Purpose	Connection to a Step in the Framework
Acquiring patient information	Eliciting information about the patient subjectively	Collecting initial data in the HOAC 2 framework.
Acquiring objective tests and measures	Asking about objective tests	Conducting the examination and analyzing data. Seeking data about objective measures. (HOAC II conduct the initial examination)
Making an assessment	Any statement that proposes multiple hypotheses about the patient problem	Generating a hypothesis about why the problem exists or used in the initial examination strategy where an initial set of hypotheses are generated from available data and from the patient identified problems. (HOAC II step generating initial hypothesis in formulate examination strategy)
Cues acquired	Statements that summarize information about the patient either subjectively or objectively	Generating patient identified or non-patient identified problem list from data collected. (HOAC II patient identified/non-identified problems)
Hypothesis generated	Any statement that represents a PT diagnosis	Generating a hypothesis as to why the problem exists (HOAC II step)
Clinical decision generated	Any statement that represents a PT clinical decision towards treatment appropriateness	Deciding if referral or consultation is necessary from the hypothesis generated from the refined list of problems generated from the hypotheses generated or from the test performed. (HOAC refine problem list, referral if necessary)
Hypothesis reconsideration	Any statement that proposes reconsideration of the first diagnosis suggested	Refining hypotheses from conducting the examination, analyzing data, carry out additional tests (Conduct the Examination, Generate hypothesis)
Clinical decision reconsideration	Any statement that proposes reconsideration of the clinical decision made	Refining the clinical decision made based upon the need for consultation or referral.

Table A.2. (continued).

Strategies employed	Order and organization of the evaluative process	Relates to the logical progression of following the HOAC 2 framework or other clinical reasoning strategy to progress towards a diagnosis.
Missing information	Information not enough to generate a diagnosis	Relates to the diagnostic phase of the HOAC 2 framework. May trigger a return to the collection of further subjective or objective data.
Difficulty with hypothesis generation	Any faulty determination of the patient problem based upon information gathered	Generating a hypothesis as to why the problem exists or a rationale for the hypothesis.
Difficulty with clinical decision-making	Any faulty determination of the appropriateness of PT treatment based upon information gathered	Generating a rationale for consultation or referral based upon available data.
Reasoning strategies utilized	Reasoning about pain, trial and error, following protocol, rule in/out, hypothetical deductive, pattern recognition	Relates to the types of strategies employed during clinical reasoning as proposed in the clinical reasoning portion of the framework.
Reasoning about pain	Notate the type of reasoning strategy used, Using the pain description and aggravating/relieving factors to guide reasoning. Considering chronicity, severity, and irritability	Relates to the types of strategies employed during clinical reasoning as proposed in the clinical reasoning portion of the framework.
Trial and Error	Notate the type of reasoning strategy used, No plan for reasoning or hypothesis from the beginning, reasoning appears randomly generated, no clear movement from one structure to another	Relates to the types of strategies employed during clinical reasoning as proposed in the clinical reasoning portion of the framework.
Following Protocol	Notate the type of reasoning strategy used, following a standard protocol—reference to a protocol to guide evaluation	Relates to the types of strategies employed during clinical reasoning as proposed in the clinical reasoning portion of the framework.

Table A.2. (continued).

Rule In/Out	Notate the type of reasoning strategy used, beginning with one or more hypotheses, reasoning about that hypothesis, and moving on to another hypothesis	Relates to the types of strategies employed during clinical reasoning as proposed in the clinical reasoning portion of the framework.
Hypothetical deductive	Notate the type of reasoning strategy used, Generating hypotheses and using an organized plan of testing to rule out or rule in. Demonstrates ability to shift hypotheses with contradictory information.	Relates to the types of strategies employed during clinical reasoning as proposed in the clinical reasoning portion of the framework.
Pattern Recognition	Notate the type of reasoning strategy used, Making a primary hypothesis to a matching patient description from prior experience. Using examination to confirm a hypothesis and explaining data findings in light of diagnosis.	Relates to the types of strategies employed during clinical reasoning as proposed in the clinical reasoning portion of the framework.
Strategies employed—in HOAC order	Order and organization of the evaluative process. Relates to the discourse of the student as they are reasoning through the clinical case.	Following the sequence and strategy of the HOAC framework.
Strategies employed—out of HOAC order	Order and organization of the evaluative process. Relates to the discourse of the student as they are reasoning through the clinical case.	Not following the sequence and strategy of the HOAC framework.

Appendix K: Table A.3 Inductive Codes Related to the Clinical Reasoning Process Added from First and Second Pass Coding and Peer Debriefing.

Table A.3. Inductive Codes Related to the Clinical Reasoning Process Added from First and Second Pass Coding and Peer Debriefing.

Code	Definition
5-10 minutes spent to collect patient subjective, 0-5 minutes spent to collect patient subjective, >10 minutes spent to collect patient subjective	Relates to the amount of time spent collecting data
Certainty in clinical decision	A statement of confidence in the clinical decision to treat or refer
Clarifying physical therapist role	A statement that clarifies scope of practice or role of a physical therapist
Considering non-patient-identified problems	Using information gained from steps in the HOAC framework to guide reasoning, hypothesis generation, or treatment rationales that were detected by the PT and not identified by the patient
Considering patient identified problems	Using information gained from steps in the HOAC framework to guide reasoning, hypothesis generation, or treatment rationale that were stated by the patient
Cued for HOAC order by interview	Interview prompted order of evaluation flow during think aloud
Cues acquired—knowledge support	Cues used by the student to support the reasoning process through knowledge (sense making cues)
Diagnosis correct	Correct diagnosis achieved
Diagnosis correct but not specific	Diagnosis was in the right system, but not articulated as a specific diagnosis
External factors influencing hypothesis generation, diagnosis decision, or clinical decision	External factors like scope of practice or participant background influence hypotheses, diagnoses, or clinical decisions
Generating problem list	Problem list generated from patient or therapist identified problems
Hypothesis correct	Correct hypothesis formulated
Hypothesis correct but not specific	Hypothesis formulated for correct system, but not specific to a diagnosis
Reasoning about patient factors	Using factors in the medical history, patient identified, or non-patient identified problems in the reasoning process
Treat and refer for physical therapy	HOAC—a decision to treat and refer

Table A.3. (continued).

Treatments not best evidenced for condition	Treatment is not the best evidenced for the condition in the case, in this case, arterial insufficiency, should be graded aerobic exercise
Treatments proposed	Participant proposes possible treatments for the patient condition
Uncertainty in diagnosis	Uncertainty in diagnosis obtained expressed by the participant.

Appendix L: Tables A.4. and A.5. Inductive Codes of Student Participants' Perceptions.

Table A.4. Inductive Codes Related to Student-Participants' Perceptions of Clinical Reasoning Influences, Added from First and Second Pass Coding and Peer Debriefing.

Code	Definition
Knowledge supports clinical reasoning	Statements that allude to gains in knowledge supporting clinical reasoning, a need for knowledge to support clinical reasoning
Lack of knowledge as a reason for error or influencing reasoning	Statements that allude to a lack of knowledge as a cause of error or faulty clinical reasoning.
Need for knowledge to support treatment decisions	Participant cites need for increased knowledge in reference to treatment
Need to collect more objective data to confirm diagnosis	Participant states need for more objective data to support reasoning
Need to collect more subjective or health history information	Participant states a need for more subjective information to support clinical reasoning
Knowledge from coursework supports clinical reasoning	Participant states that new knowledge from classwork influences clinical reasoning or treatment rationale
Previous experience influencing diagnostic reasoning	Interview states that previous experience affects diagnostic process
Previous experience influencing treatment rationale	Participant states that treatment rationale was influenced by past experience
Confidence is needed for clinical reasoning.	Participant makes a statement alluding to the need for confidence for clinical reasoning.
Process management is needed for clinical reasoning.	Structure is needed to assist in the clinical reasoning process.

Table A.5. Inductive Codes Related to the Mobile Application's Utility/Effect, Added From First and Second Pass Coding and Peer Debriefing.

Inductive Code	Code Definition
Participant liked application	Participant states that they had positive feelings toward the application

Table A.5. (continued).

Mobile application needs changes	Any changes that student-participants recommend to the mobile application
Mobile app increases comprehensiveness of objective tests	Mobile app affected type or amount of objective information collected
Mobile application increases/changes subjective questioning	Mobile application increases subjective information collected or changes noted in questioning (new inductive code)
Mobile application narrows problem focus	Problem list or reasoning more focused from application
Mobile application structures diagnostic process	Structure is provided for diagnostic process from application
Mobile application supports knowledge acquisition	Mobile application helps in gaining knowledge
Mobile application increases focus/specificity to the objective exam	Application helps to focus reasoning process by giving different objective tests and questions, focusing the exam (new inductive code)