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Clinical Reasoning in First- and Third-Year Physical Therapist Students

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Background and Purpose. The development of clinical reasoning skills is a crucial component of professional physical therapist education. Prior research has described reasoning patterns in novice and expert practitioners, yet little is known about how professional physical therapist (PT) students develop clinical reasoning skills. The purpose of this study was to explore how first-year PT students perform clinical reasoning in comparison to third-year PT students in their final semester.

Subjects. A simple random sample of 6 first-year (mean age 23.1 years) and 6 third-year (mean age 27 years) Doctor of Physical Therapy students were recruited.

Methods. Participants completed an evaluation and treatment plan for a simulated patient case while performing a think-aloud. Participant strategies were identified based on patterns of examination data collected and hypotheses formed. Participant hypotheses and final assessments were coded for dimensions of the International Classification of Functioning, Disability and Health (ICF).

Results. Qualitative differences were found between first- and third-year students in categories of hypotheses formed, assessments made, and treatments selected. Six reasoning strategies were identified. Third-year students demonstrated use of the 3 more sophisticated strategies, while first-year students used only the 3 simplest strategies. First-year students demonstrated 3 faulty patterns of reasoning that were not present in the work of the third-year students.

Discussion and Conclusion. This study provides a preliminary description of clinical reasoning strategies used by first- and third-year physical therapist students. Third-year students demonstrated reasoning strategies previously described in studies of novice practitioners, while first-year students demonstrated reasoning errors not previously described in the literature. These findings may inform curricular design to promote effective development of clinical reasoning.

Key Words: Clinical reasoning, Professional physical therapist education.

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BACKGROUND AND PURPOSE

As physical therapists have gained greater autonomy as professionals, clinicians and educators have placed greater emphasis on clinical reasoning. Clinical reasoning has been defined as the precursor to any clinical decision-making or action: a complex reasoning process incorporating cognition, metacognition, and specific knowledge that distinguishes healthcare professionals from technicians and ancillary staff.[1,2] Due to the naturally ambiguous nature of patient cases, clinical reasoning requires practitioners to develop a reasoning framework when not all of the facts about a case are known.[3] Additionally, clinical reasoning is a highly context-dependent skill, often considered an "interactive phenomenon" rather than an isolated process.[1] The process of clinical reasoning encompasses how a healthcare practitioner's knowledge is translated into patient care.[3] Effective clinical reasoning skills allow PTs to make informed treatment decisions without total reliance on protocols.[4]

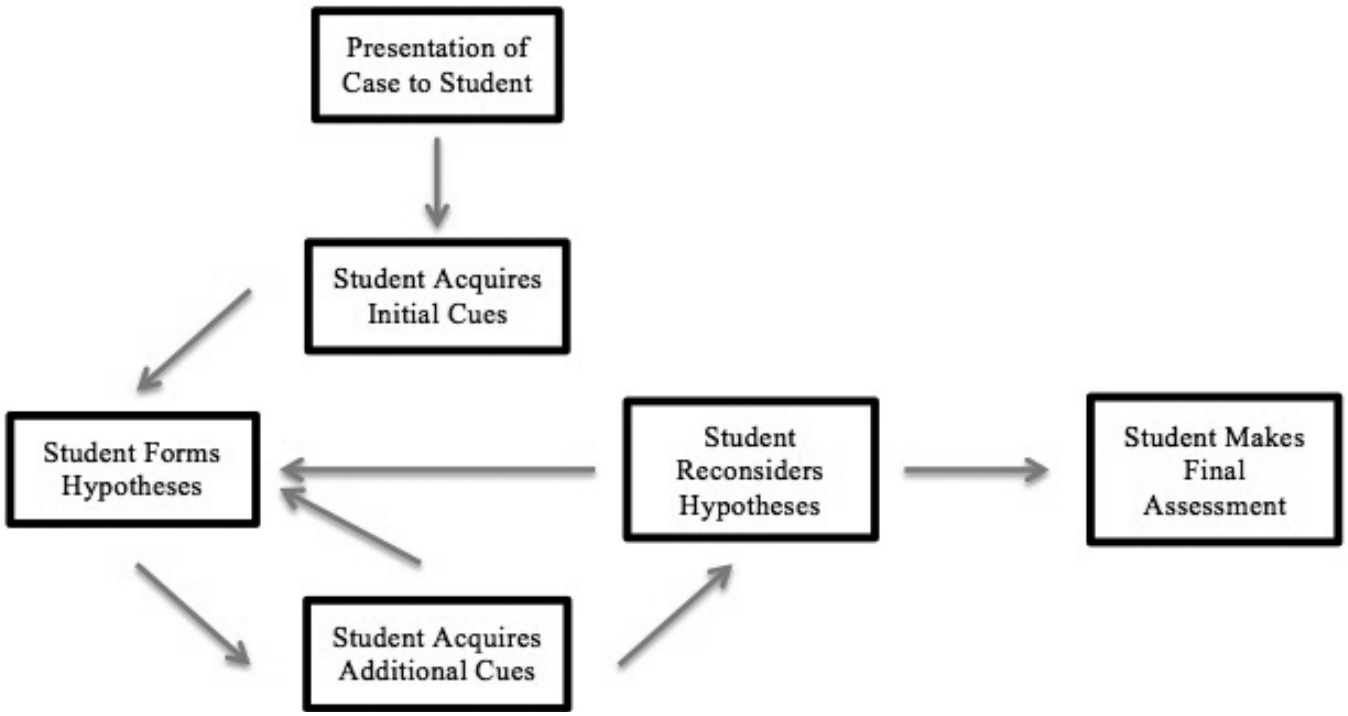
Professional physical therapist education aims to prepare students to be autonomous practitioners. Clinical reasoning abilities reflect how students transfer knowledge acquired in the classroom to clinical patient care. This study explores the clinical reasoning processes of beginning level physical therapist (PT) students by addressing the following questions: (1) What strategies do PT students take in collecting and interpreting information during the examination and assessment process? (2) What strategies do they use in creating a patient-care plan? (3) How do the strategies used by first-year students compare to those of third-year students?

Literature Review

The theoretical framework for this study draws on 3 previously described models of clinical reasoning: the hypothetico-deductive process, forward reasoning models, and patient-centered reasoning. Prior studies of clinical reasoning have indicated greater use of the hypothetico-deductive process by novices, while experienced clinicians increasingly use forward and patient-centered reasoning.[5] The following sections further describe these models and their value for research.

The hypothetico-deductive model emerged from early studies on medical clinical reasoning and suggested that a general problem-solving model could be applied to clinical reasoning.[6] The hypothetico-deductive process encompasses 4 primary activities: cue acquisition, hypothesis generation, cue interpretation, and hypothesis evaluation.[7] The hypothesis concept encompasses a broad range of thought, from diagnostic ideas to any structure/process that may be contributing to the patient's state.[3] Several studies across medicine and physical therapy have identified use of the hypothetico-deductive process by novice clinicians, but have found minimal evidence of this process in expert practitioners.[5,8,9] Other authors suggest that experts do resort to the hypothetico-deductive process when they are working on problems outside of their usual realm of practice

Figure 1. Framework for Clinical Reasoning in DPT Students



or managing particularly difficult cases.[10]

Knowledge-based or pattern-recognition models focus on the organization of knowledge and its availability as the determinants of diagnostic reasoning.[11,12] Schmidt and colleagues[13, 14] proposed that expert health care providers encapsulate knowledge into "illness scripts" that contain complex interwoven networks of knowledge. These include enabling factors for particular diagnostic categories, as well as "instance scripts" that draw on prior encounters from episodic memory during the diagnostic process. Mandin et al[10] suggested that experts have medical knowledge organized in elaborated networks that can be retrieved and efficiently applied to problem-solving. They suggested that it is the organization, structure, and accessibility of relevant knowledge, and not a general problem-solving strategy, that is crucial in medical problem-solving.

More recent studies of clinical reasoning and expertise in physical therapy have shifted the focus towards an interactive process centered on the patient. In these studies, expert physical therapists exhibited minimal use of hypothetico-deductive problem-solving and focused more on the patient's values and experience, while collaborating with the patient and the patient's family in their reasoning process.[8,15] Expert physical therapists exhibited an intuitive flow of social interaction with clinical assessment and therapeutic intervention, and the ability to grasp pertinent cues.[16] Edwards et al[17] suggested that clinical reasoning involves a dialectic between deductive reasoning processes and the constructivist narrative of the patient's experience and values.

While there are many similarities, especially in the diagnostic process, between physical therapy and medicine, there are several factors unique to the practice of physical therapy that suggest the necessity of further study of reasoning processes specific to physical therapy. Physical therapists exhibit a focus on movement patterns, movement impairments, and task requirements for movement. Embrey et al[18] studied the reasoning processes of expert and novice pediatric physical therapists and found that both expert and novice PTs used movement scripts to organize, encode, and retrieve relevant clinical information. Specific to shoulder pain, expert PTs exhibited a focus on movement impairments in addition to traditional orthopedic testing in their reasoning and assessment processes.[19] Additionally, PTs must identify and address the consequences of the injury or disease process in addition to the diagnosis itself.[20] These factors suggest that in order to understand the development of clinical reasoning in PTs, studies must specifically include PT students, and avoid drawing inferences solely from research on medical or nursing students. Literature on the clinical reasoning of PT students, however, is limited.

The few clinical reasoning studies that have included PT students studied only students who had completed at least 1 full-time clinical experience.[5,9,21,22] Overall, these studies indicate that PT students perform patient examinations less thoroughly and process their findings at lower levels of complexity compared to experienced clinicians. However, these studies do not provide a model for PT student reasoning among students with no clinical experiences. In order to examine clinical reasoning in a PT student population, I have adapted the hypothetico-deductive model employed by novice practitioners.[5] As illustrated in Figure 1, there are 3 primary areas for analysis: the types of cues the student acquires (both initial and additional cues), the types of hypotheses the student forms and reconsiders, and the final assessment(s) the student makes.[5,7,23] In addition to each of these primary assessment areas, secondary levels of analysis can address the thoroughness and organization of the overall process. The student's level of accessible knowledge likely determines the organization of information collected, and the effectiveness of hypotheses generated and evaluated.

With high productivity demands on clinicians serving as clinical instructors,[24] students should enter the clinic with at least a minimal capacity for clinical reasoning. Didactic course-work ideally should prepare students for the demands of clinical reasoning, yet no studies to date have explored the concept of clinical reasoning in students who have completed only didactic course-work. In light of the importance of clinical reasoning for effective outcomes in physical therapy, the

Table 1A. Program Organization

Year	Fall	Spring	Summer
First	1 Anatomy Developmental Anatomy Physiology Biomechanics General Pathology Research Methods I	2 Kinesiology Neuroanatomy I Orthopedic Pathology PT Examination (lab) Acute Care PT (lab) Research Methods II	3 Orthopedic PT I (lab) Neuroanatomy II Neurophysiology Neuropathology Modalities Pre-clinical (2 week clinical)
Second	4 Orthopedic PT II (lab) Neurologic PT (lab) Motor Control and Learning Cultural Diversity and Psychology Research Methods III	5 12-16 weeks clinical affiliation	6 Cardiopulmonary PT (lab) Pediatrics (lab) Rehabilitation PT (lab) Anatomy II (lab) Diagnostic Imaging Ethics
Third	7 12-16 weeks clinical affiliation	8 Leadership and Ethics Applied Administration Geriatrics Advanced Patient Management Complementary, Alternative Medicine and Wellness	9 16 weeks clinical affiliation

Table 1B. Topics Addressed (at Time of Study) in First-Year Courses

Orthopedic Pathology	Physical Therapy Examination
• Intro to orthopedic pathology • Differential diagnosis of pain • Soft tissue injury and healing • Osteoporosis, fractures and management • Osteoarthritis • Rheumatoid arthritis and related disorders	• Utility of physical therapy measures & tests • Patient interview & lab • Hypothesis development and planning the objective • Patient handling & palpation lab • Medical screening • Observation of motion: goniometry and end feel assessment/ interpretation

development of this skill must be addressed in professional physical therapist education programs, but to this point, no work has traced the development of reasoning processes in physical therapist students.

METHODS

Prior studies investigating clinical reasoning have used 2 differing approaches to data collection: contextually grounded observations and interviews,[5,17,18,25-28] and laboratory-based simulated cases or knowledge assessments.[12,29-32] The methodology used by James,[21] using a role-play of a patient examination, provides an opportunity to document the students' approaches to both data collection and interpretation during the patient assessment task. In this approach, the researcher provides verbal information from a written case (subjective and objective examination data) in response to student inquiries about the patient. For the student population in this study, the verbal exchange approach to patient simulation used by James[21] was preferable to a typical simulated patient (where the student actually performs the manual tests on an actor).[33] This was due to the initial data collection being performed at a time when the students had not yet been introduced to hands-on clinical skills. Additionally, the information-focused format allowed for assessment of the cognitive approach without confounding by the students' limited technical skills.

Participants

I selected a random sample of 6 student volunteers from a first-year class in a professional Doctor of Physical Therapy program who were beginning their second semester of course work. Table 1A presents the order of coursework and clinical affiliations in the Doctor of Physical Therapy program. Table 1B describes the specific clinical content the first-year students had completed at the time of the study. In summary, the first-year students had covered the general process of differential diagnosis at the tissue level (assessing muscle, ligament, nerve, bone, and joint), and had been introduced to the patient interview process and the concept of hypotheses formation, but had not explicitly addressed differential diagnosis for shoulder pathologies. All first-year students had experience volunteering or working as aides in outpatient orthopedic clinics. None of the first-year students had been athletic trainers or physical therapist assistants prior to physical therapist school. I selected a second group of 6 third-year students from the same

Table 2. Participant Background Information

	Pseudonym	Age	Prior Clinical Experience
First-Year Students	Shelly	24	• Aide in orthopedic clinic (1 year) • Hospital outpatient clinic • Inpatient observations (1 day)
	Misty	22	• 200 hours total outpatient ortho • Outpatient neurologic (40 hours) • Acute (8 hours)
	Maya	23	• Aide outpatient orthopedic w/ aquatic therapy (1.5 years) • Acute (1 day)
	Jenn	25	• Aide outpatient orthopedic w/ geriatrics and pediatrics (3 years) • Hospital volunteer: NICU and some adult
	Kelly	23	• Outpatient orthopedic (private practice) • 1 day neurologic clinic
	Cathy	22	• 3 months 3 days/week observing outpatient orthopedic • Observing athletic training
Third-Year Students	Cara	29	• Aide in outpatient orthopedic (9 months) • 15 hours inpatient, 15 hours SNF (volunteer) • 12 week spinal injury rehab affiliation • 12 week outpatient orthopedic affiliation
	Gina	26	• Summer jobs as aide (3 clinics, 2 outpatient orthopedic, 1 orthopedic/aquatic) • 8 weeks - outpatient neurologic affiliation • 8 weeks - outpatient orthopedic affiliation • 12 weeks - outpatient orthopedic affiliation
	Felicia	32	• 15 months as aide (orthopedic and aquatic) • 7 weeks - inpatient and cardiac affiliation • 8 weeks - outpatient orthopedic affiliation) • 12 weeks – inpatient acute, rehab, and outpatient orthopedic affiliation
	Liz	25	• CHOC volunteer (7 months, 2 hours/week) • Aide (outpatient orthopedic) • 12 weeks - outpatient orthopedic affiliation • 12 weeks – rehab affiliation
	Elysse	25	• Aide in outpatient orthopedic before PT school • 12 weeks - acute inpatient affiliation • 12 weeks - outpatient orthopedic affiliation
	Mary	25	• Aide in outpatient orthopedic (1 year prior to PT school) • 8 hours hospital volunteer; 8 hours outpatient neurologic volunteer • 12 weeks - outpatient orthopedic affiliation • 12 weeks - pediatrics (school-based) affiliation

program, who were at the end of their eighth and final semester of coursework, to serve as a comparison group. All of the third-year students had completed at least 12 weeks of full-time clinical affiliations in outpatient orthopedic clinics. The mean age was 23.4 years for students in the first-year group and 27.0 years for students in the third-year group. Table 2 details student experience prior to participation in this study.

Procedures

I met with participants one-on-one in a quiet room to complete the study procedures. After presenting the instructions (detailed in Appendix A), I presented each participant with a brief description of the patient. Participants then asked the researcher questions about the patient (based on the elements of the physical therapist patient interview and examination) in order to gather the data necessary to make a proper patient assessment. The researcher read from the written case description in response to the participant's questions regarding both subjective and objective examination data (Appendix B displays complete patient case). If the participant requested information that was not included in the written case, the researcher responded, "That was not tested." Making the assessment of the patient entailed stating the final hypotheses that the participant felt were most supported by the cues collected. Most participants moved directly into making an assessment when they had collected as much information as they deemed necessary. Examples of the student-researcher interaction during the think-aloud are detailed in Table 3. Following the examination and assessment process, I presented the participant with the complete patient case, providing a chance to reassess the diagnosis if desired. The partici-

Table 3. Examples of Think-Aloud Student (S) –Researcher (R) Interactions

Opening interactions	R:	You are working in an outpatient orthopedic clinic and you have a new patient on your schedule. Before the patient walks in, you have the following information: Jana is a 50-year-old female complaining of left shoulder pain with a gradual onset starting 6-months ago. She cannot associate the onset with any specific incident or cause. She is complaining of difficulty with reaching upper cupboards and styling her hair.
	S:	OK, the end?
	R:	That is the description you get. So you tell me, what are you thinking and where are you going?
	S:	OK, so first I wanna find out more about the pain and I would probably ask um Jana if she could um either show me on herself where the pain is or if I had a diagram, if she could draw it on the diagram, um where the pain was specifically in her shoulder, if it was anterior posterior in deep, superficial, as stuff like that (Misty)
Acquiring patient interview information	S:	Has she had any other injuries associated with her shoulder?
	R:	Not with the L shoulder, but she had bursitis in her R shoulder 10 years ago.
	S:	Bursitis in the R, so nothing with the elbow or the wrist?
	R:	No other UE injuries
	S:	And nothing with the neck?
	R:	No neck injuries
	S:	OK, um, and what's her occupation like?
	R:	She is a receptionist at a dental office
	S:	So she sits a lot, not necessarily, I wonder if her desk height, well, uh, that wouldn't do it (motioning typing on keyboard) (Jenn)
Acquiring objective tests and measures	S:	I guess lastly I shoulder check the strength and compare it to both sides. Of the shoulder, do you want me to be specific?
	R:	Be specific about what muscles or actions you want to test
	S:	OK, so definitely flexion
	R:	Alright flexion on her right was considered within normal limits
	S:	OK
	R:	Flexion on her left was a 3+/5
	S:	Did she get pain with that? You would say that, right?
	R:	No pain
	S:	And then abduction?
	R:	Was also normal on the right, left was a 3+
	S:	3+, OK, external rotation?
	R:	External rotation was a 3/5 on the left
	S:	3/5, internal?
	R:	Internal actually wasn't tested (Elysse)
Making the assessment	S:	like, in like, forward tilt [describing the scapula] and causing a lot of pain right here so that when she further puts it in that position it causes a lot of pain for her. Um
	R:	So where is that taking you?
	S:	Um I'm taking, I guess that's taking me to a diagnosis. Um, and I would, I don't know what the formal dx at all would be, but I would say that um she has trouble with posture and um it's putting a lot of pressure on her inferior capsule so we would need to work on um work on her kyphosis her forward head posture and um hopefully that would straighten out the humeral head in the glenoid fossa which would naturally make it better when she would abduct her arm. (Maya)

Table 4. Framework for Analysis

First Stage Coding	Information Collected (Cues Acquired)	Participant statements during the think-aloud eliciting information about the patient coded for elements of PT exam both subjective and objective (defined by *Guide to Physical Therapist Practice*[38]).
	Hypotheses Generated	Any diagnostic idea[3] mentioned during the think-aloud coded for domains of ICF with additions for emergent codes.
	Hypothesis Reconsideration (Evaluation)	Mentioning a hypothesis again during the think-aloud (after collecting further information) and re-evaluating that hypothesis in light of that information.
Second Stage Coding	Strategy	Defined by order and organization information collected and hypotheses generated, the nature of hypotheses, and the relationship of the hypotheses to the information acquired.
	Stumbling Blocks	Inappropriate interpretation of information collected or in incorrect hypothesis evaluation during the think-aloud (based on information collected)
	Thoroughness of Examination	Information acquired during the think-aloud compared to diagnostic criteria (cues required for diagnosis): Missing information = insufficient cue acquisition to make the patient's correct diagnosis

Table 5. Codes for Hypotheses and Assessments[a]

Source	Code	Definition
Derived From ICF[39]	Medical	**Health Conditions** include diseases, disorders and injuries.
	Structure	**Body Structures** include anatomical parts of the body such as bones, joints, muscles, and their components.
	Function	**Body Functions** are physiological or biomechanical functions of body systems.
	Activity	**Activity** includes the execution of a task by an individual.
	Participation	**Participation** is involvement in a life situation.
Derived From Data	Phase	**Stage of healing** includes inflammatory, fibroblastic, and remodeling phases.
	Mechanism	**Mechanism of injury** includes overuse, acute, and systemic.

[a] For the final assessment, the modifier "incorrect" was added if the participant named an incorrect structure, diagnosis, or phase of healing.

pant then described a preliminary treatment plan for the patient based on findings. As each participant described how patient treatment would unfold, the researcher prompted concrete examples of treatment ideas.

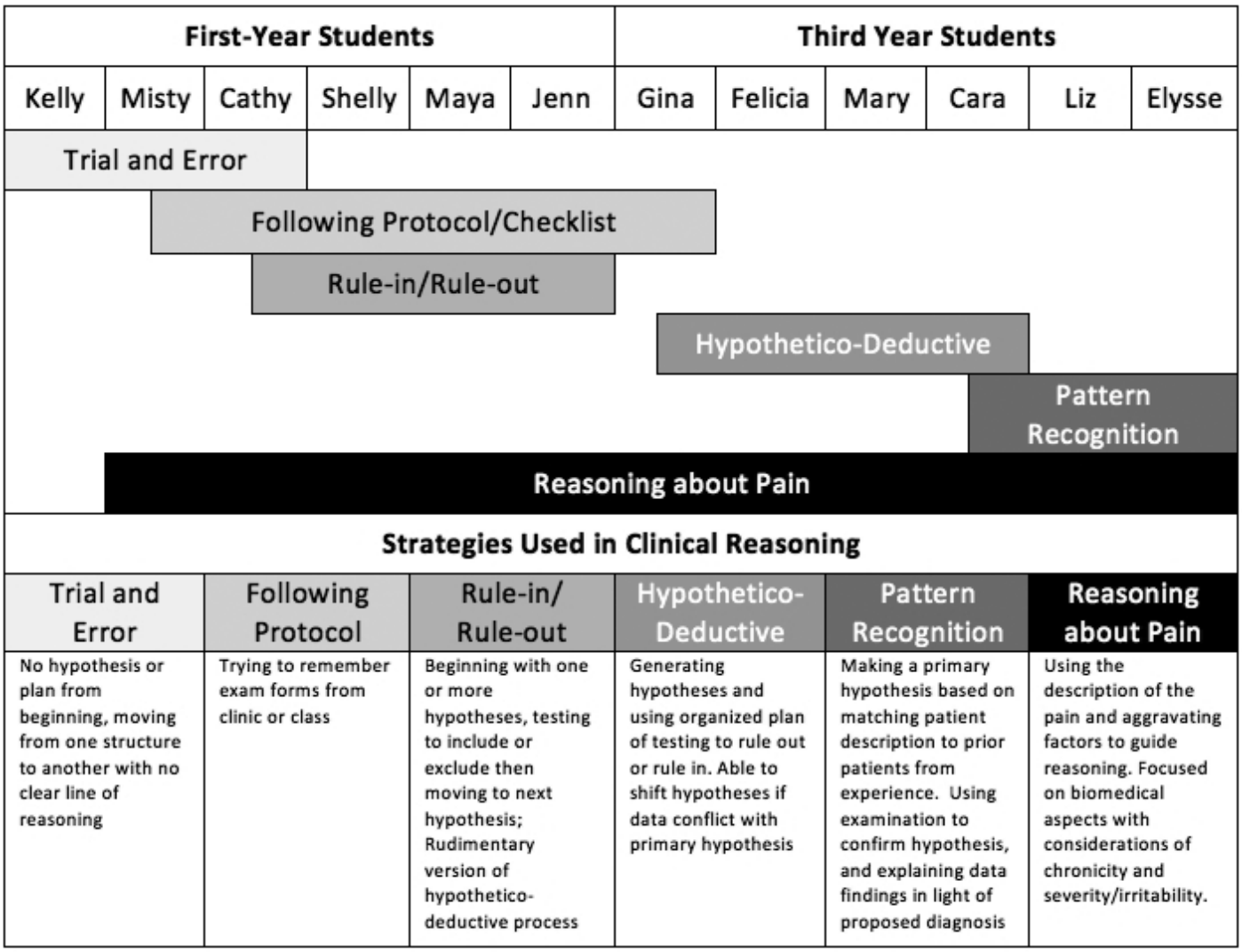
In addition to thinking out loud through the process,[34-36] participants were allowed to write down their findings throughout the assessment and treatment-planning in order to help them remember and organize thought processes. However, they were not given any specifications about what to write down. Throughout the think-aloud process, I took notes on the type and order of information the participant acquired and the hypotheses formed. Immediately following the think-aloud, I used these notes to guide the interview regarding the participant's process through the patient case. I developed the interview questions based on the retrospective think-aloud and debriefing procedures in order to probe participant thinking at a level not possible during a concurrent think-aloud.[34,37] The think-aloud process and interviews were audiotaped, and all participant notes completed during the diagnostic and treatment-planning processes were collected for analysis. (See Appendix C for a complete interview guide).

Data Analysis

Following each participant session, I transcribed all audio data from the think-aloud process and the interview. I used a 2-stage approach to coding and analysis. The first stage was derived directly from the adapted model of clinical reasoning (Figure 1), while the second stage of coding was built on the findings from the first, specifically examining the thoroughness of the examination process, the types of reasoning errors committed, and the overall strategy employed. (See Table 4 for an overview of coding process).

In the first stage of coding (structural coding),[38] I coded all information sought by the participant during the think-aloud based on the categories of tests and measures defined by the American Physical Therapy Association (APTA) in the *Guide to Physical Therapist Practice*.[39] Participant statements made during the think-aloud involving evaluation of possible pathologies, structures responsible, or patient limitations were coded as hypotheses, based on Barrows and Feltovich's[3] definition of a hypothesis as any diagnostic idea or structure/process associated with the patient's condition. I then categorized each hypothesis for diagnostic category based on the domains of the ICF,[40] with slight modifications to account for the inclusion of assessment

Figure 2. Student Reasoning Strategies



Strategies Used in Clinical Reasoning

Trial and Error	Following Protocol	Rule-in/ Rule-out	Hypothetico-Deductive	Pattern Recognition	Reasoning about Pain
No hypothesis or plan from beginning, moving from one structure to another with no clear line of reasoning	Trying to remember exam forms from clinic or class	Beginning with one or more hypotheses, testing to include or exclude then moving to next hypothesis; Rudimentary version of hypothetico-deductive process	Generating hypotheses and using organized plan of testing to rule out or rule in. Able to shift hypotheses if data conflict with primary hypothesis	Making a primary hypothesis based on matching patient description to prior patients from experience. Using examination to confirm hypothesis, and explaining data findings in light of proposed diagnosis	Using the description of the pain and aggravating factors to guide reasoning. Focused on biomedical aspects with considerations of chronicity and severity/irritability.

of mechanism of injury and stage of healing (summarized in Table 5). I selected the ICF as a taxonomy for categorizing student hypotheses because it allows for identification of the consequences of the injury process, which are relevant to PT intervention, as well as the diagnosis of the injury itself.[20] For each participant, I tallied the number of hypotheses formed in each category. Additionally, I coded each participant's final assessment of the patient using the same system. In the second stage of analysis (pattern coding),[38] I identified each participant's strategy for approaching the patient examination and evaluation, based on the patterns of information collected and hypotheses considered (Figure 2). I also analyzed the information collected by students during the think-aloud to determine if they considered the patient's quantity and quality of movement.

Using expert consensus of diagnostic criteria for adhesive capsulitis[41] (the simulated patient's diagnosis) during the second stage of coding, I categorized participants as missing diagnostic information if their think-aloud process did not include all critical factors. I coded participant statements that contained a misinterpretation of examination findings as stumbling blocks. These included misguided examination findings, and conclusions or hypothesis formed by inadequate or inappropriate findings. These data were analyzed alongside the information sought and used to identify how the participants managed concepts with which they had limited knowledge (Table 4).

Data from the treatment planning portion of the think-aloud task were coded for elements of physical therapy intervention as defined by APTA.[39] I compared participant interventions to examination findings, as well as the interventions indicated as effective for the patient's condition (based on current physical therapy literature).[42-44] I also considered participant interview data regarding sources of knowledge[45] for their interventions in determining the strategy used for planning treatment. Finally, I noted student comments that indicated a preference for interaction with a real patient.

In order to triangulate across data collection methods[46,47] (think-aloud, problem-solving and interview data), I created a process sheet for each participant, detailing the order of information collected and hypotheses generated. Next, I inserted relevant interview data as memos that corresponded to each stage of the problem-solving process. I then compared these process sheets with the notes the participant had taken during the patient case problem. This process allowed for direct comparison between think-aloud and interview comments on each aspect of the patient case problem.[37] In order to enhance the dependability of the analyses, I maintained an audit trail, linking the development of the analyses to the original data transcripts.[47] At each stage of analysis, I discussed my findings and the data with colleagues in physical

Table 6. Examples of Reasoning Strategies

Considering Movement	"I'm trying to figure out which muscles do rotation (laughs) I guess the right SCM, there we go (turning head) the right SCM. Ok, but when she would rotate left, she felt tight on the left." (Misty, think-aloud) "I would like to, watch her perform her activity, so actually lifting and putting things overhead in the cabinet and while she's doing that I would also like to know how much weight the thing is that she's lifting or carrying so how heavy those things are and what compensations did I see?" (Gina, think-aloud) "I'm continuing my thought process with adhesive capsulitis based on her pattern of movement. Especially with females they try to hike their shoulder through their neck, cuz they can't get that range." (Liz, think-aloud)
Reasoning About Pain	"OK so now because the pain's radiating, I have a feeling there's some sort of nerve being pinched, and because of the dull achey sensation, I feel like it's something in the joint that has some sort of insult or injury." (Jenn, think-aloud) "I'm thinking it's musculoskeletal. … some kind of muscular strain, or ligamentous or capsular, problem because if it was in the joint itself, I feel like it would hurt all the time rather than just with the overhead motion. And if it's better with rest it seems like it could just be like an overuse injury, or even impingement if it's only overhead motion. But if it's a dull aching, I don't think impingement would produce a dull aching. I think that would be more like a sharp pain. So, I'm thinking, ligamentous or muscular." (Shelly, think-aloud) "Usually neurological symptoms have people describe it as tingly or zinging. So the fact that it's an ache. It doesn't really coincide with the typical description of a neurological symptom." (Elysse, think-aloud)
Trial and Error	"Let me think, I don't know, I don't think I know, I'm trying to think of the different structures in the shoulder now like, acromion, humerus. So there's joints. Ok glenohumeral joint, acromioclavicular joint, and there's another joint. Oh no! I honestly don't know. Where would I go from here? I'm kind of stuck." (Misty, think-aloud) "I can't think of any ligament tests or ones that I would do, mainly because we haven't talked about the shoulder a whole lot, so I can't really think of anything. I guess I would probably palpate and to see if the pain was localized to right around the shoulder joint or if it extends anywhere else. Maybe ask if there's any referred pain. If she's getting pain in any other areas, and then maybe if there is referred pain you might consider that it would be nerve impingement. So, I guess I would test compression of the spine to see if that can reproduce any of her symptoms at all." (Kelly, think-aloud)
Following Protocol	"Let me think. Social history, current history, past medical history. So right now I'm trying to think. Dr. B. gave us a little sheet that she likes to use to fill out, and I'm trying to visualize the sheet and see if I completed all of her items." (Misty, think-aloud) "Well in my mind I was trying to go through the patient eval form, and because it's (pain) on the top of the form." (Cathy, interview) "It kind of threw me off not having an evaluation sheet, because that cues me when I do get off track or if the patient goes on a tangent it refocuses me. So not having that I was constantly in my head thinking what comes next, what comes next… that's why I was more sporadic. I feel because I didn't have a set guide to follow. Otherwise, I was just trying to remember everything I needed to ask. And I did forget things and had to ask you later." (Gina, interview)
Rule in/ Rule out	"So I would static muscle test. To kind of rule in or out joint versus muscular versus ligamentous." (Shelly, think-aloud) "I'm thinking that she might have an impinged capsule or something like that. Maybe a hypomobile capsule that hurts on the, inferior capsule or something. Or the tendon, the supraspinatus tendon, maybe has a tear so I would do a static test, and then I would probably palpate that (the tendon) because we learned the musculotendinous unit. And then I would palpate. So static, stretch, and then palpate." (Maya, think-aloud)
Hypothetico-Deductive	Frozen shoulder, rotator cuff, overuse. So I'm kind of thinking overuse the least, so I want to rule it out first. So my question for her would be does she participate in any sports, activities where she uses her shoulder a lot? Is she a swimmer? Does she enjoy swimming or is she a tennis player? (Felicia, think-aloud) I would want to ask more about her activity. What she's been doing leading up to that (her injury)? But definitely the first thing that comes to mind is impingement. I'd do more tests for that. And then ask about histories of falls or anything that would maybe have a little possible tear in the shoulder leading up to some kind of space occupying lesion. And then go on from those questions. (Mary, think-aloud)
Pattern Recognition	OK so right now I'm thinking, insidious onset of maybe an adhesive capsulitis, she fits into that general population. Especially with flexion and external rotation. (Liz, think-aloud) So kind of fitting this person, each piece of info, trying to say, OK, who have I treated and who have I seen that was similar to that and what did they have and how did I treat them. (Cara, interview)

therapist education in order to clarify my interpretations and probe for any biases.

RESULTS

Figure 2 summarizes the reasoning strategies used by the participants. The 12 participants demonstrated 6 different strategies with varying levels of sophistication as they completed the think-aloud process. Most participants used a combination of 2 or more strategies through different portions of the think-aloud. Each strategy included consideration of movement, as indicated by the information the participants gathered about the patient. For example, all of the third-year students considered observational movement analysis, active range of motion, and passive range of motion in developing and evaluating their hypotheses. All first-year students considered at least 1 movement factor, such as active range of motion or strength. All participants, except 1 first-year student, used the strategy "reasoning about pain." Several first-year participants struggled to use the strategy appropriately, interpreting any radiating pain as indicating nerve injury, for example. Other first-year students appropriately interpreted the patient's pain descriptions as indicative of soft tissue or joint injury, and were able to use this information to guide the remainder of their examination. One third-year student used the "following protocol" strategy in a process more similar to the first-year students than to the other third-year students. Table 6 presents participant quotations illustrating these strategies.

Figure 3 and Table 7 summarize the students' hypotheses generated during the examination process. There was no difference between first-year and third-year students in the mean number of hypotheses generated (mean 12.83 for first-year, 13.17 for third-year, median 12.5 for both groups). Overall, the first-year students generated more hypotheses categorized as structure, while the third-year students generated more hypotheses focused on medical diagnoses. Both groups generated an equal number of function hypotheses, while all other categories were mentioned less frequently. Third-year students reconsidered hypotheses they had generated an average of 4.5 times, while first-year students only reconsidered hypotheses an average of 1.8 times. The categories of the students' final assessments followed closely to the hypotheses they had generated (Table 8 and Figure 4). Similar to their hypotheses generated, the first-year students' final assessments focused on the anatomical structure and function categories, while the third-year students primarily made medical diagnoses their final assessment.

Figure 3. Hypotheses Formed

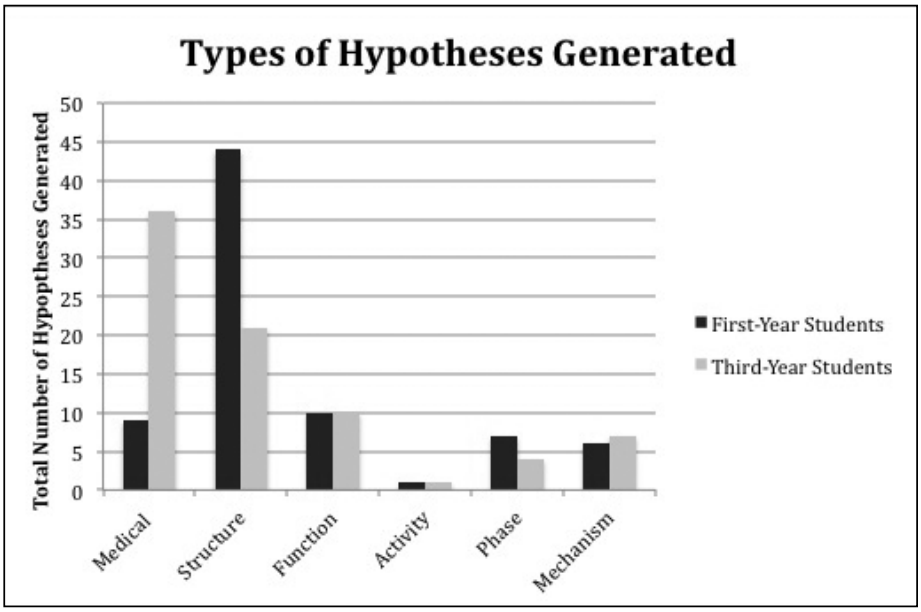


Table 7. Contingency Table for Student Hypotheses

Hypothesis Category	First-Year Students	Third-Year Students	Total
Medical	9	36	45
Structure	44	21	65
Function	10	10	20
Activity	1	1	2
Phase	7	4	11
Mechanism	6	7	13
Total #	77	79	156

Table 8. Contingency Table for Assessments

Assessments	First-Year total	Third-Year Total	Total
Medical	1	5	6
Structure	2	0	2
Incorrect Structure	1	0	1
Function	3	4	7
Activity	1	1	2
Mechanism	1	0	1
Phase (incorrect)	1	0	1
Total #	10	10	20

Information critical for diagnosis was based on expert consensus of diagnostic criteria for adhesive capsulitis.[41] Five of the 6 first-year students failed to solicit at least 1 piece of critical diagnostic information, while all of the third-year students successfully collected all critical diagnostic information.

Participant reasoning and decision-making in the face of uncertain information (stumbling blocks) followed 3 primary patterns. Each first-year student demonstrated at least 1 stumbling block during the patient

Figure 4. Students' Final Assessments

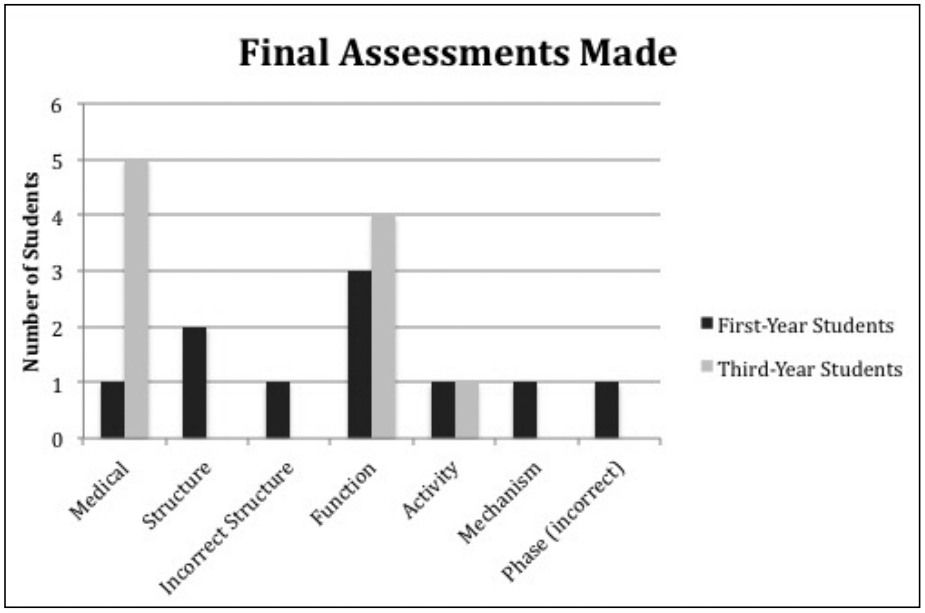
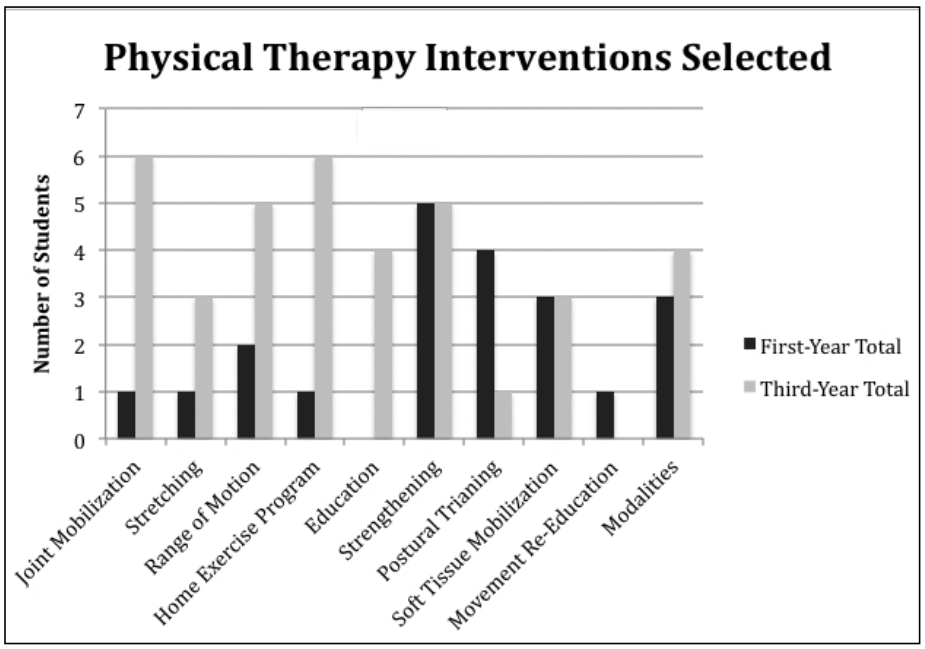


Figure 5. Treatment Interventions Selected



assessment process. Four first-year students jumped to conclusions by taking 1 piece of information that was necessary but not sufficient for final decision-making. They then made the assessment without considering the other findings necessary for drawing that conclusion. Two first-year students demonstrated perseveration, while taking necessary, but insufficient pieces of diagnostic information to rule in particular hypothesis. They then continued to rationalize that hypothesis as other information was collected, even when it ran counter to the participant's conclusion. Two first-year students demonstrated disregard when they chose to ignore unfamiliar information and move on, ruling it out because they did not know how to assess it.

Figure 5 summarizes the students' selected interventions. Third-year students included an average of 6.2 interventions in their plans, while first-year students included an average of 3.5. The third-year students' interventions focused on joint mobilization, stretching, range of motion, home exercise programs, patient education, and strengthening exercises, which have all been included in the literature on physical therapy interventions for adhesive capsulitis.[42-44]

Table 9 provides examples of the students' approaches to treatment planning. First-year students focused on strengthening and postural reeducation, with most students indicating they felt the patient's pain level was too high for stretching or mobilization. Third-year students tailored their treatment plans with considerations for the specific patient as an individual, including attention to the patient's activity preferences, while the first-year students based their plans on their general concept of a shoulder patient. Additionally, third-year students considered the patient's prognosis (based on information collected during the examination) in determining how long and how intense the interventions should be. Finally, all third-year students cited patients with adhesive capsulitis that they had treated in the clinic as their primary source for treatment ideas. In contrast, first-year students drew on personal experience with shoulder injuries and observations of other PTs treating patients. . Overall, third-year students indicated they would have preferred to interact with a real patient, while first-year students reported being comfortable with the simulated experience.

DISCUSSION

This study has described the strategies and patterns of reasoning used by first- and third-year Doctor of Physical Therapy students in completing a clinical case scenario. The reasoning strategies indicate a hierarchy of sophistication, with individual participants demonstrating combinations of patterns at times. This finding suggests that as one develops towards greater sophistication in reasoning, incorporation of advanced strategies with simpler familiar patterns becomes commonplace. The use of multiple strategies, especially the combination of the hypothetico-deductive model and pattern recognition (used by some third-year students), may offer problem-solving flexibility, similar to the approaches used by expert physicians.[10]

The hierarchy of sophistication in the strategies employed by students supports the knowledge-based theories of clinical reasoning. Using the trial-and-error strategy requires minimal organization of knowledge. In contrast, using pattern recognition requires extensive working knowledge of diagnoses and enabling factors. The rule-in/rule-out strategy requires knowledge of conditions necessary to include a hypothesis, while the hypothetico-deductive process requires advanced knowledge in order to generate appropriate hypotheses earlier in the process. As students develop greater working knowledge of clinical conditions, they can advance

Table 9. Student Quotations From Treatment Planning

Treatment Selected	"I'm assuming that she's still kind of inflamed. So I would want to work on decreasing that before I really did any movement, cuz I would, they would just continue to provoke the pain. So yeah, I would just do rest and ice um, maybe um some heat, like a heat packs um, if there is any kind of like muscular problems that are like, you know, pulling the spine. That are you know, impinging the nerves, to try to get them relaxed. But yeah, I wouldn't do ROM or strength training quite yet." (Kelly, first-year, think-aloud) "So, the treatment plan would be, to work on her posture, so to maybe stretch out the pecs to get her, to get her chest to open up so she can, bring her shoulders back so you want to work on retracting the shoulders as well um, and then also work on her forward head posture so that she can get more of her upper spine." (Jenn, first-year, think-aloud) "I would try to help strengthen um the posterior neck muscles either by having her do isometric things by like having my hand here to Ok push against my hand, try to move my hand, different things just strengthening her neck. And then different things at home, too, like tilt your review window just up a little bit, that kind of forces you to, I have to do that too, so that's why I know that. But, as for the actual shoulder and the actual shoulder pain, I still really couldn't tell you much about that!" (Misty, first-year, think-aloud)
Specificity of Treatment	"I felt like since we did see a lot of shoulder patients, that it kind of gave me like a foundation of exercises to pick from that I could apply to what I think her diagnosis was." (Shelly, first-year, interview) "And I was trying to actually picture myself in the clinic to see if, you know, I could, remember any patients that we had seen with the shoulder or any shoulder problems. Not, and not any specific shoulder problems, just any shoulder problems." (Cathy, first-year, interview) "I would start hands on with her. Just doing some joint mobilizations, kinda to stretch out the capsule a little bit, obviously explain to her what I'm doing. Specifically inferior was the most restricted, so definitely working on the inferior glide. Also she was anteriorly seated so, posterior glides. And, getting more functional activities, so practicing reaching for things, cuz she has difficulty with that." (Elysse, third-year, think-aloud) "And then I would probably, at the end of all of this, possibly for pain relief, maybe TENS. Maybe not, it kinda depends if she's had it before, some people love it, some people hate it, some people can't tolerate it, you put it on them, you turn it up a tiny bit and they're crawling off the table." (Felicia, third-year, think-aloud)
Considering Prognosis	"…my main goal is to help her maintain as much function as possible and keep her strength from decreasing as much as possible. So I wanna do, range of motion especially into external rotation, so like towel slides and then sustained holds. So we can get that capsule stretch, stretched out. But because of the pathology itself, that's gonna be a long time of doing that before we see a lot of anything. So my main goal is scapular stabilizers lots of shoulder and then soft tissue to the upper traps to help with decreasing pain in that area." (Liz, third-year, think-aloud) "And then I'd try to start educating my patient on what a frozen shoulder is, being that it's where the capsule gets tight, and it has a freezing, a frozen and a thawing stage that, we can try, we can help with. But it has its, a mind of its own. It's going to take its time and what we'll do while you're, while it's going through this, is we'll keep you moving as much as we can. We will keep you, keep your range of motion, we'll, we'll help you try to keep you strengthening, we'll help get you to that thawing point." (Felicia, third-year, think-aloud)
Difference from a Real Patient	"So you think about that, you think of everything that you've learned in the past 4 weeks, which is all like the subjective the testing and what that means. And then, I felt like that would be really hard and then trying to communicate that to a patient, and not making myself seem like I don't know what I'm doing." (Shelly, first-year, interview) "I think when they're in front of you and you're, like eye contact, I think I would have been more organized, just leading off her, well, like when you're abstractly thinking of this patient, and what they look like and how they responded to you, and I don't know, I would have had a lot more flow." (Mary, third-year, interview) "I'm more of a visual person. So, if I'm working on a person or like very hands on. Like, it wouldn't be as choppy. And it helps organize my thoughts. So if I can visualize it, like, oh this is what I forgot." (Liz, third-year, interview)

from the rule-in/rule-out strategy to the hypothetico-deductive process. The relationship between student levels of available knowledge and reasoning strategies employed provides support for the knowledge-based theories of clinical reasoning.

The reasoning processes used by students in this study reflect those described in the clinical reasoning literature in several ways. Similar to patterns noted in medical students during think-aloud case study assessments, first-year students focused hypotheses on anatomical structures, while third-year students focused on medical diagnoses.[29] The difference in focus between first- and third-year student hypotheses is likely generated from their respective coursework as at the time of this study. First-year students had only completed their foundational science courses, while third-year students had already completed extensive clinical coursework and affiliations. Comparing the treatment-planning processes of first- and third-year students revealed that third-year students gave much greater consideration to the patient as an individual. This discrepancy in patient consideration is similar to the differences described between novice and expert PTs in practice.[16,48] Although the task used in this study did not allow direct student-patient in-

teraction, the majority of third-year students indicated that they would have preferred engaging with a real patient. First-year students, however, felt the study task was easier to complete than an actual patient encounter.

Several other factors revealed in studies of expert and novice physical therapists are relevant to the behaviors of first-year students in this study. Jensen et al[16,48] noted that novice clinicians in their studies were more mechanical and bound to external structures (protocols, evaluation forms) than experts. At the time of this study, first-year students had been provided with a structured form and practice in completing their subjective interviews. While they were not provided with the form for this study, most first-year students tried to remember the form's content while completing the patient case. This study revealed that those who were able to use that external structure to support their preliminary reasoning processes used a more sophisticated (rule in/rule out) strategy during their objective examination. This suggests that while it may be restrictive at times, external support (evaluation sheets, protocols) provides developmental scaffolding that allows the novice to complete the reasoning process as sophisticated processes develop. Black et al[49] acknowledged this progression away from external structure in their study of PT clinicians during their first year of practice.

All first-year participants in this study exhibited faulty reasoning at some point during the think-aloud process. This was caused by recently learned information that the students were struggling to incorporate into their reasoning processes. Doody and McAteer[5] noted errors in cue evaluation in their novice participants, linking mistakes to a limited ability to interpret clinical patterns. First-year student errors also indicate limited knowledge about necessary and sufficient conditions for including or excluding a hypothesis. The findings of this current study provide further understanding of these errors by describing 3 patterns of reasoning (jumping to conclusions, perseveration, and disregard) that students with limited knowledge utilize.

The stumbling blocks encountered by several of the participants may be a reflection of first-year students' inability to distinguish critical from non-critical factors in the examination and assessment process. Jensen et al[16] noted this difference between expert and novice clinicians in the ability of the experts to grasp important cues and not be distracted by superfluous factors. Livingston and Borko[50] noted this same pattern in comparing student teachers to expert classroom teachers. The students lacked a framework for determining important factors. Several of the stumbling blocks exhibited in this current study reflect participant inability to determine whether examination findings are critical or not. This often resulted in excessive focus on distracting cues that were not critical to the assessment of the patient.

One first-year student's case indicates an additional stumbling block not evident in other student work. This student was unable to form an assessment after collecting information. After reviewing the full written case, however, the student was able to form an accurate functional diagnosis. This finding suggests that the ability to make sense of clinical information presented, as well as the ability to appropriately seek clinical cues may involve different developmental processes. This case illustrates the importance of using case scenarios, where the participant does not receive all critical information up front.[51] The information-seeking process reveals more depth of how a student would reason in the face of a true clinical scenario.

Students in this study exhibited reasoning about movement, a characteristic of clinical reasoning by physical therapists not described in the medical reasoning literature. Both first- and third-year students used active and passive range of motion testing in their diagnostic reasoning and treatment planning. Third-year students included consideration of both quantity and quality of movement and related their findings to the patient's activity and participation limitations. Prior studies of expert and novice PTs have illustrated this focus on movement patterns, movement impairments, and task requirements for movement.[18] Specific to shoulder pain, expert PTs exhibited a focus on movement impairments in addition to traditional orthopedic testing in their reasoning and assessment processes.[19] These findings suggest that an important topic of further study would be how this capacity for reasoning about movement develops.

Implications

Understanding the developmental process of clinical reasoning skills and stumbling blocks encountered by PT students can inform curriculum design and pedagogy to promote effective clinical reasoning skills in PT students. Classroom coursework must equip students with the skills necessary to become aware of their own clinical reasoning thought processes, as time for explicit analysis of reasoning during clinical affiliations is limited due to the demands of patient care.[52] Successful pedagogy depends on the instructor's understanding of the students' current level of relevant knowledge.[53] By describing patterns of reasoning demonstrated by first-year PT students, this study contributes to the groundwork necessary for developing efficient teaching methods in professional PT education programs. Prior experimental studies examining teaching strategies for clinical reasoning have suggested that teaching students to work from a combination of hypothetico-deductive and pattern recognition strategies improves accuracy in diagnosing ECGs.[54-55] All students in this current study demonstrated multiple strategies during the problem-solving task. Consequently, teaching methods that help students use multiple strategies may also be valuable in physical therapist education. The stumbling blocks identified in this study can guide educators in identifying and assessing the types of reasoning errors students are most likely to make when first learning to apply knowledge in patient care.

Further analysis of which constructs students had the most difficulty transferring to clinical applications may have implications for teaching those concepts in didactic courses. Prior studies have suggested that how information is presented to medical students impacts how they organize and apply their knowledge.[13,30,56-58] Additional research should investigate the impact of different teaching methods on beginning level student performance during clinical reasoning tasks.

This study has several limitations that should be addressed by future research. First, the clinical problem-solving task used in this study, while similar to those used in prior studies of clinical reasoning,[21,29] does not allow for assessment of interpersonal factors and narrative reasoning. Additionally, the cross-sectional design does not allow analysis of the developmental process of clinical reasoning skills (follow-up studies are currently in process to address this limitation). The design of this study also does not account for factors that influenced the development of the students' reasoning skills. Future investigations into various programs and multiple points in the curriculum, however, can provide more insight into these factors.

The completion of the primary coding and data analysis by only one researcher contributes to consistency in coding, but may increase the risk of researcher bias. This study presents a preliminary analysis of clinical reasoning in a student population not previously examined. In addition, this study has demonstrated a research methodology capable of eliciting reasoning patterns in students prior to their clinical experiences, and distinguishing these patterns from those of more experienced students. Future research may replicate or extend the findings of this study.

The development of clinical reasoning skills in professional PT students is a cru-

cial aspect of professional physical therapist education programs. This study has identified patterns of reasoning exhibited by students who have not yet received clinical problem-solving instruction. These findings contribute to our understanding of the developmental process from PT student to novice practitioner to expert clinician.

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Appendix A. Instructions to Participants

Instructions to Participant:

For the first part of this task, you will be working to make an assessment of a clinical patient case. In order to gather the information about the case, you need to ask for whatever information you want from me. This includes subjective and objective information. If there are things you might observe (ie, posture) or test (AROM, etc), just ask and I will tell you the result of that test or observation.

While you are completing this process, you need to discuss everything you are thinking out loud. This means saying why you are asking for the information you are asking for, or saying how the information affects your thinking about the case. One way to think of it is that you are trying to help a classmate understand this case, so you need to explain the choices you are making as you are making them. During the majority of this case process, you should be talking. You are to make an assessment of the patient in this case. In other words, describe, as Steve would say, "What is wrong with this patient?"

Throughout the process you may write down any information you would like in order to help you in your work on the case.

I'm going to play you an example of working through this process: (play recording)

Once you have made your assessment, you will be given the paper with the entire case information. You will be allowed to re-evaluate your assessment if there is any information on the paper that changes your thinking about the case.

After you have made your assessment, you will be asked to develop and describe an initial treatment plan. You should be as specific as possible in explaining your plan. Throughout this process you will be "thinking out loud" as you discuss your thought process.

Do you have any questions before we start?

To get you used to thinking out loud, I'm going to have you do a warm up activity. I want you to tell me how many windows there are in your house or apartment. As you are counting them, talk out what you are doing and how are you counting them.

Appendix B. Patient Case Scenario

(This case draws from several patient profiles and does not represent any one individual.)

1. Brief description (read to participant at start of think-aloud): Jana is a 50-year-old female complaining of left shoulder pain with a gradual onset starting 6 months ago. She cannot associate the onset with any specific incident or cause. She is complaining of difficulty with reaching upper cupboards and styling her hair.

2. Subjective Information
    - A. Personal Information
        - i. Left handed
        - ii. Hobbies: Painting, French-braiding/styling her hair
        - iii. Lives in a house w/ her husband (no kids)
        - iv. Exercise: stationary cycling (30 minutes, 4 days/week), occasional outdoor walking/hiking; no strength training
    - B. Occupation
        - i. Receptionist at a dental office
        - ii. Needs to reach file boxes on top of file cabinets
    - C. Pain description
        - i. Constant dull ache, aggravated with motion
        - ii. 7/10 with activity, reduces to 4-5/10 after an hour of rest
        - iii. Radiates from shoulder to elbow
        - iv. Affects sleep if sleeping on L side
    - D. Aggravating factors
        - i. Shoulder motion (any)
    - E. Relieving Factors
        - i. Rest
    - F. PMH
        - i. Treatment for this condition
            1. Two cortisone shots over past 3 months (no relief of symptoms)
            2. NSAIDs (no relief)
        - ii. No hx of L shoulder problems
        - iii. R shoulder bursitis 10 years ago (treated with cortisone injections)
        - iv. Hysterectomy (7 years ago)
        - v. HTN (controlled w/ meds)
        - vi. Multi-Vitamin and Calcium supplements

Appendix B. Patient Case Scenario

3. Objective
    - A. Posture
        - i. Mild kyphosis
        - ii. Forward head
        - iii. Rounded shoulders, humeral head forward in glenoid
        - iv. L scapula elevated 1 inch higher than R

    - B. AROM
        - i. Scapulohumeral rhythm: L restricted scapular movement with scapular hiking, asynchronous
        - ii. Shoulder AROM
            1. R: WNL
            2. L: 95° flexion, 60° abduction, 25° ER, 70° IR
                a. Pain with all AROM, greatest with ER
        - iii. Cervical ROM:
            1. WNL
            2. Tight on L with R side-bending and L rotation
    - C. PROM
        - i. L: 100° flexion, 65° abduction, 30° ER, 80° IR
            1. Increased pain with each
            2. (Capsular pattern)
        - ii. Isolated Glenohumeral flexion: 70°
        - iii. L Glenohumeral accessory mobility: limited in all directions especially inferior glide

    - D. MMT
        - i. R shoulder WNL
        - ii. L scapular stabilizers (middle and lower trapezius): 3/5
        - iii. L serratus anterior: 3-/5
        - iv. L shoulder ER: 3/5
        - v. L shoulder flexion/abduction (within available range): 3+/5
        - vi. Abdominals: 3-/5

    - E. Palpation
        - i. Tender L upper trapeizius
        - ii. Tender L arm

    - F. Special Tests
        - i. Negative impingement sign, Negative Speeds test
        - ii. Negative drop arm/Supraspinatus sign

    - G. Neuro Screen
        - i. DTRs: 2+ throughout (WNL)
        - ii. Sensation: intact throughout

Appendix C. Interview Guide

1. Tell me a bit about yourself
    a. How did you get interested in physical therapy?
    b. What was your experience prior to coming to Chapman?
        i. Where did you go for undergrad?
        ii. Did you do volunteer work in physical therapy?
        iii. What about work/career experience?

2. Walk me through your experience in working on the patient case (questioning guided by researcher's notes taken during think-aloud)
    a. Tell me about where your thought process started (what were your first thoughts?)
    b. How did you proceed through the case?
    c. How did you feel approaching this case?

3. How did you decide what questions to ask? (Researcher probes with actual questions asked by the participant during the think-aloud)
    a. What did you do with the responses you got to the questions?

4. How did you draw your conclusions about a diagnosis?
    a. How do you feel about your conclusion?

5. Walk me through your thinking about a treatment plan (Researcher probed using plan participant developed during think-aloud)

6. How did you come up with your ideas for treatment?

7. How did you feel about the treatment planning part of the process?

8. What factors influenced your thinking about this problem?
    a. How did your experience prior to PT school affect your thinking?
    b. How did your course work during the fall semester affect your thinking?
    c. How did the instruction of the courses affect your thinking?
    d. Can you identify any other factors that affected your approach to this problem? If so, what were they?

Questions 9 and 10 were not used in the analysis for this paper

9. What is the role of the patient in your thinking about this case?

10. What do you think are the most important/central qualities/skills for physical therapy practice?