A Developmental Approach to Evaluating Competence in Clinical Reasoning

C. Scott Smith

ABSTRACT

In the past two decades there has been tremendous worldwide interest in assessing the clinical competence of learners in medical education. This interest marks a philosophical shift toward greater objectivity, accountability, and predictive power in the evaluation of trainees. One of the core competencies in medical education is clinical reasoning. Because veterinary and human medical training share several similarities and differences, a review of the current state of clinical reasoning competency assessment in medical education may be useful for veterinary educators. This article covers the core competency of clinical reasoning (not other important competencies, such as physical examination or communication) and reviews research from medical education on the development of clinical reasoning and its implications for the transition from novice to expert. Four common stage-related learner difficulties are described: reduced knowledge, dispersed knowledge, tunnel vision, and the outsider. Specific approaches to measuring competence in clinical reasoning for each developmental level are recommended. Finally, two specific examples of evaluation based on a developmental approach to clinical expertise, the RIME (reporter, interpreter, manager, expert) system and the Script Concordance Test (SCT) methods, are discussed.

Key words: professional competence, cognitive science, education

INTRODUCTION

Medical education over the past two decades has seen a worldwide change in focus from the *process* of training (which things are taught and how) to the educational *outcomes* of training (competencies—what is actually learned). For instance, during the 1990s several competency-based outcome initiatives were implemented in the United States, Canada, and Great Britain.[1–5] The starting points for developing these lists were as different as societal needs,[2] the ideal attributes of a successful doctor,[4] and examples of ''best practices'' in medical education,[3] but all resulted in remarkably similar lists of key competencies.

Medical and veterinary education share broad similarities, with some differences. Both involve new vocabulary, a large and rapidly growing body of scientific knowledge, the importance of physical examination and communication skills to achieve optimal outcomes, and practice in complex systems of care. Medical school graduates cannot practice in the United States without at least two years of post-graduate training, whereas only 10–15% of veterinary graduates participate in internships or residencies. Medical education began as two strictly pre-clinical years devoted to learning vocabulary and basic science in the classroom, followed by observation and limited supervised practice,[6] and has evolved toward level-appropriate clinical responsibility integrated with instruction and newer learning methods throughout the curriculum at most schools. Various learner-centered (as opposed to lecture-centered) methods, such as problem-based learning (PBL),[7] case-based learning (CBL),[8] and scheme-based problem solving,[9] have been shown to improve outcomes and are now common. These may be important ''wheels'' that need not be reinvented as reform of veterinary medical education moves ahead.

Most clinical evaluation systems identify several important clinical competencies such as knowledge and clinical reasoning, communication, self-directed learning, procedures and physical examination, and successful integration into a health care system. Excellence in one area contributes to but does not ensure proficiency in another. This article focuses on the competency of clinical reasoning.

Miller has suggested that knowledge is the foundation from which competence and clinical performance derive.[10] In the same review he hints at the developmental nature of this process through his pyramid for clinical assessment, from knowing, to knowing how, to showing how, to doing. The developmental journey from novice to expert, from knowing facts to applying knowledge efficiently in a clinical context, has been observed in many health professions. This article briefly reviews the evidence for developmental changes in the clinical reasoning of medical trainees, then proposes a developmental approach to competency-based evaluation that could be adopted by other health professions.

COGNITIVE RESEARCH IN MEDICAL EDUCATION

Early research in cognitive science found a very low correlation between clinical reasoning performances across different cases, suggesting that expertise is not a general problem-solving skill but, rather, is ''context dependent.''[11] An expert isn't using more effective general problem-solving strategies that can be identified and taught. Instead, he or she is using more efficient storage and access structures in memory that are based in part on prior experience. The research focus then shifted to understanding the development of efficient memory structures.

Patel and his group at McGill University presented study participants with detailed written case descriptions. Using propositional analysis of think-aloud transcripts, they identified participants' memory for the facts, their descriptions of the underlying pathophysiology, and their diagnoses. They compared the reasoning of medical students and experienced physicians and looked closely at the ''production'' (if→then) rules used. They found that experts make more inferences, while novices use more verbatim recall of relevant information. Novices also remember irrelevant details, whereas experts tend not to do so.[12] In another study Coughlin and Patel found that experts use forward reasoning (from data to diagnosis) and are not bothered by information's being presented out of logical sequence in cases where the inferences are largely made on clinical facts. In cases that require integration of clinical and biomedical information, however, order of information is more important, and experts are more apt to resort to backward reasoning (forming a hypothesis to the data). By contrast, students are not particularly sensitive to information order or type of case.[13] These studies suggest that the efficient memory structure of experts (1) is largely clinically based, (2) allows them to focus quickly, fill in relevant details, and ignore irrelevant details, but (3) may break down if mixed biomedical and clinical facts are required or if an expected narrative structure is perturbed.

Bordage and colleagues reevaluated Patel's findings on reasoning and the development of memory structures using structural semantic analysis rather than propositional analysis. Propositional analysis assumes a causative network if antecedent→consequent production rules (*syntax*). Semantic analysis adds to this ''horizontal'' dimension a ''vertical'' dimension of hierarchical logical abstractions or meanings by associating clinical information with binary qualitative properties (*semantics*). For example, the syntax might include the propositions weakness→motor, numbness→sensory, middle finger→C8 level, left only→unilateral, whereas the higher-level, inclusive (semantic) concept might be C8 radiculopathy. Bordage et al. found that poor students show weakness in both syntax (logical propositions) and semantics (overarching concepts). As students improve, they begin to show syntactical richness (greater number and more connectedness of logical propositions), followed by improving semantics (concept development). Experts show reduced use of syntax and deal primarily with abstract concepts (semantics).[14]

These and other studies are summarized in another paper that outlines the development of medical expertise. Learners begin with real or apparent ''reduced knowledge'': they are unable to connect clinical findings in the case to their own store of medical knowledge, either because this store is insufficient or because it is inaccessible. Next, they improve their store of ''dispersed knowledge'' but still have trouble connecting it to the clinical facts. This difficulty manifests itself in long lists of differential diagnoses or suggested tests without clear focus or prioritization. With further experience, the clinical findings are understood within a framework of semantic qualifiers (e.g., acute/chronic, central/peripheral) and case histories and write-ups become more focused and pertinent. Finally, the expert quickly recognizes a holistic pattern in the patient's clinical findings, labeling it with a high-level term (often unintelligible to novices) and immediately focusing on missing information.[15]

Groups from McMaster University and Universiteit Maastricht have summarized their own and other cognitive science research with a staged theory of clinical reasoning development.[16] In the first stage, the learner is developing knowledge and integrating it into elaborated causal networks. In the second stage, these elaborated networks are compiled into higher-level abridged networks. The third stage comes with the onset of clinical experience and the shift of focus from causative networks to organization of clinical features into ''illness scripts''—generic production rules involving enabling conditions, fault, and consequences. Finally, the integration of abridged causative networks and illness scripts occurs with specific patient encounters in the form of ''instance scripts.''

In order to test this hypothesis, the researchers performed a series of experiments using a method similar to Patel's but including a distinction between biomedical and clinical propositions (based on the object of the proposition). There were two important findings. First, the peak use of biomedical propositions occurs in the early intermediate stage (end of medical school). This has been termed the ''intermediate effect'' and has been observed elsewhere. Second, post-hoc analysis revealed that experts incorporate the highest overall degree of biomedical information; it has simply been encapsulated into higher-level clinical propositions (in other words, it is not forgotten or inert). These findings support a three-stage model of expertise development: (1) acquisition of biomedical knowledge, (2) practical experience, and (3) encapsulation of theoretical and experiential knowledge into efficient clinical propositions.[17]

This body of research suggests that learners start by acquiring formal knowledge. Initially, this is decontextualized biomedical knowledge. With clinical experience, isolated biomedical knowledge is subsumed by higher-level clinical concepts. With more extensive experience, this formal knowledge is blended with specific cases to form prototypical patterns, and pattern recognition becomes the norm in familiar domains. Thus, experience guides formal diagnostic reasoning and makes it more efficient, while formal diagnostic reasoning provides checks and balances for experiential intuitions to avoid premature closure.

A CONCEPTUAL MODEL OF LEARNER DEVELOPMENT

One useful way to conceptualize these data is to create a simplified model of learner development. Our model sees learners on a journey from ''newcomer'' to ''old-timer'' within a community of medical practice (see Figure 1).[18,19]

The community of medical practice in this model is represented by three concentric circles. The area between the outside circles, like the skin of an avocado, is the only part that the external world has access to—formal descriptions (objective attributes and rules). The next section, like the fruit of the avocado, is the *raison d'être* for this community—patient care. The center of this model, like the seed of the avocado, is responsible for sustaining and regenerating this community—continuous medical improvement (advancing knowledge and reassessing values).

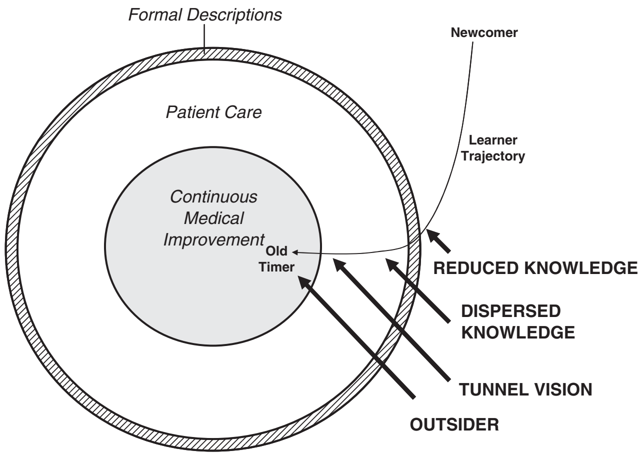

Figure 1: The community of medical practice model of learner development

Learners, in this model, progress through four expected stages of competence. Their trajectory starts outside the circle, and they are expected to have *reduced knowledge*; they are not yet familiar with the jargon, the objective attributes, or the rules and scientific principles that govern this domain. This is not unlike entering a foreign culture and needing to learn the language and the local forms of nonverbal communication.

If learners are on the proper trajectory, they will have gained basic knowledge during their preclinical years. Learners in the second stage (early clinical years) have trouble grouping knowledge together in ways that are applicable to patient problems and clinical diagnoses. They have *dispersed knowledge*, recognizable by long lists of clinical features, possible diagnoses, and tests they would like to order. Newer models of medical education that mix clinic exposure with instruction and self-directed learning throughout all four years of the curriculum help to ameliorate this problem. In the current climate of information explosion, no amount of static knowledge is sufficient, and self-directed learning skills are also important.

With clinical experience, learners on the proper trajectory begin to group information into clinically useful and relevant scripts, schemas, or prototypes. However, these cognitive groupings may not fit each specific clinical presentation. Learners at this third stage often suffer from *tunnel vision*, which can result from either objective errors (premature closure) or subjective errors (stereotypes). To some extent, we all have a degree of tunnel vision throughout our practice careers (see below).

In the final stage, learners have a rich catalog of scripts, schemas, and prototypes and have begun to develop instance scripts and pattern recognition in familiar domains. They can quickly focus on missing or discrepant clinic facts. However, they are still *outsiders*, seeing themselves as proficient individuals and not as dynamic elements in a complex health care team. Cognitive competencies now shift to coordination of care and continuous personal improvement. The tasks now include understanding when one needs help from colleagues and how to integrate that help successfully; being an advocate for one's patient in a complex system; and unabashedly seeking out places where personal performance can improve even further.

MEASURING COMPETENCE AND TEACHING AT EACH LEVEL

Commensurate with these developmental stages are differences in the ideal learning process. It is useful to conceptualize this process as a parallel trajectory of relationships moving from teacher–student, through master–apprentice, to clinician–client, and finally to coach–player. The process goal in a teacher–student relationship is to create knowledge, and in a master–apprentice relationship it is to increase skill to create a quality product. The goal in a clinician–client relationship is to create insight, and the goal in a coach–player relationship is to create optimal performance. While I present both the relationships and the evaluation methods as separate and stage-like, in reality they are intermixed in a fluid way at all stages. It is simply that one process may predominate, and paying attention to the role you adopt as teacher in a given situation gives you a clue as to what the learner might need.

Reduced Knowledge

The reduced knowledge level is the norm for the preclinical years, and performance should transcend this level by the early clinical years. In many ways, assessment at the reduced-knowledge stage is the most familiar. Competency is assessed by traditional tests. If the learner appears to be stuck in this stage, faculty must make sure that the problem is truly one of a reduced knowledge and not an issue of reduced access (to knowledge), such as cultural or personal differences, performance anxiety, or lack of basic necessities such as food and rest.[20]

The teacher–student relationship at the reduced-knowledge stage uses elaboration and construction of basic concepts and should focus on mutual, limited goals around prototypical cases, incremental gains, and close follow-up. Sending the learner back to whole chapters in textbooks, a tempting maneuver at this stage, can overwhelm and functionally abandon them. Guided reading (e.g., ''Read the three pages on pulmonary function tests and how they work; then we'll discuss them'') can be helpful.

Dispersed Knowledge

Dispersed knowledge is the norm in early clinical training, and the point at which the learner transcends this level is quite variable. Dispersed knowledge requires more sophisticated competency evaluation. Recall that this is the stage where information is being synthesized into useful conceptual structures, and the evaluation process must test application of knowledge and judgment. Complex, multistage paper- or computer-based simulations may work well to assess cognitive competence at this stage. Performance evaluation in simulated contexts can also be very useful. For instance, focused observations of clinical care with structured feedback work well for the development of skills such as communication and physical examination. If the learner appears to be stuck in this stage, the cause may lie in personality traits such as an unusual amount of anxiety due to clinical uncertainty or fear of failure. These issues require special attention to a safe and comfortable learning climate.

A 45-year-old female smoker presents to the clinic because of three days of chest pain, cough and low grade fever. Her only medications are oral contraceptives and she has no allergies.

If you were thinking of…	*And then you find*	*The hypothesis becomes.*				
Pulmonary embolus	**Room air oxygen saturation 97%**	–2	–1	0	+1	+2
Bronchitis	**Wheezing**	–2	–1	0	+1	+2
Pneumonia	**Clear chest x-ray**	–2	–1	0	+1	+2

–2 the hypothesis is almost eliminated
–1 the hypothesis becomes less likely
0 the information has no effect on the hypothesis
+1 the hypothesis is becoming more probable
+2 it can only be this hypothesis

Figure 2: An example of the script concordance test method

The master–apprentice relationship at this stage focuses on *knowing how* instead of on *knowing what*. Exercises that require a commitment from the learner or comparing and contrasting the abstract description of a disease process to the case at hand can help the learner develop the necessary cognitive models. Asking learners to prioritize by likelihood, cost, disease severity, or some other criterion can help them learn to focus the diagnosis and work-up.

Tunnel Vision

Tunnel vision may become apparent in any area after dispersed knowledge resolves, and it exists to some extent throughout our clinical careers. Evaluating clinical reasoning at this stage requires sophisticated techniques to achieve a degree of realism. Recall that tunnel vision may be objective (premature closure), resulting from incomplete or incorrect scripts and prototypes (e.g., "wheezing = asthma"); or it may be subjective (stereotype), resulting from unwarranted assumptions about crucial elements of the physiological or psychosocial dimensions of the patient (e.g., "He's poor, so he probably doesn't understand how to use his inhaler"). Competency evaluation for this stage requires high-fidelity techniques such as videotaped role-plays, objective structured clinical examinations (OSCEs), and standardized patients. These techniques are often unfamiliar and threatening to the learner, so it is important to use them in early formative evaluation before they are used in high-stakes summative evaluation. If the learner appears to be stuck in this stage, it can sometimes be the first sign of a personality disorder or other serious professionalism issue.[21]

The therapeutic clinician–client relationship appropriate to this stage, is based on trust, safety, and mutual commitment. Early on, it is important to suspend judgment of the learner. Other important elements include empathy, warmth, respect, concreteness (specificity), genuineness (honesty, realness), and immediacy (telling it like it is "here and now").[22]

Outsider

The outsider stage is typically reached during post-graduate training or early practice in medical education and may present a particular difficulty for current models of veterinary training. Medical training includes evaluation of the ability of senior residents to access and participate in complex systems of care. There may also be safety for the senior resident in believing that one has finally reached a stable plateau of proficiency, and it can be difficult (or exhilarating) to find out that one is on dynamic ground that is always shifting and changing. At this stage, not even high-fidelity techniques are realistic enough to capture performance, and some form of work-based assessment is required. Keys to work-based assessment are to establish a framework of required competencies, set performance standards for professionally meaningful tasks, have a toolbox of assessment instruments (chart audits, prescription patterns, peer review, videotaped clinical encounters, etc.), and use wide sampling across content and assessors.[23]

The coach–player model for optimizing performance, appropriate to this stage, is based on a mutual commitment to personal excellence and to seamless care within a complex system. Coaches first focus on skill; the player has to be exposed to ideal performance so that he or she can see or visualize it during practice. Demonstration, video review, and high-fidelity simulators can be useful. Coaches also focus on motivation; can the players do it, do they want to, and are they willing to try? Here, the techniques of motivational patient interviewing can be mirrored in teaching (expressing empathy, developing a discrepancy, rolling with resistance, and supporting self-efficacy).[24] Coaches then help the player to overcome barriers to excellent performance that come from system issues or role difficulties (overload, ambiguity, conflict, or rigidity).[25]

Putting It All Together

While this model (see Table 1) portrays each transition as clean and uniform, this impression is far from the truth. Part of the difficulty in creating a single competency

Table 1: Summary of the learner stages, teaching, and evaluation strategies

Learner Stage	Identifying Features	Learning Process	Teaching Strategies	Evaluation Strategies
Reduced knowledge	''I don't know'' Inaccessible knowledge Absence of knowledge	Teacher–student	Survey for access Mutual, limited goals Close follow-up	Standard tests
Dispersed knowledge	Long lists Overly broad differentials Encyclopedic, no context	Master–apprentice	Focus on the patient Get a commitment Develop prototypes	Complex, multi-step paper or computer simulations Practice in simulated contexts
Tunnel vision	''I DO know'' Premature closure Inexact stereotypes	Clinician–client	Suspend judgment Create safe learning climate Challenge assumptions	Videotaped role play OSCE Standardized patients
Outsider	''I'm just fine'' Resistance to self-evaluation Failure to understand role in complex system	Coach–player	Motivate/self-efficacy View ideal/practice Problem solve	Work-based assessment • chart audits • 360° surveys • Videotape • Peer review

assessment is that learners traverse these levels at different rates. An individual learner may also be at different levels in different areas of medicine, or his or her progress may be non-linear over time. For instance, I was once proficient at delivering babies, but I surely have reduced knowledge now, partly because the field has changed and partly because I have seen no obstetrics cases for 20 years! It is often advisable to include evaluation modalities from more than one developmental level in order to adequately assess all the learners being tested. In addition, we should not view our role as faculty monolithically, as we will then miss opportunities to connect in more effective ways. For instance, a ''coach'' may be able to help a class of early learners to bond and be motivated to achieve the highest possible performance while still functioning as a ''teacher'' of information.

Then there is the matter of inadequate performance. The phenomenon of being ''stuck'' at any developmental level must be further differentiated. Has the learner's trajectory always been unusually shallow (especially on tests relative to clinical grades)? This may reflect a compensated learning disability, and formal neuropsychiatric testing should be considered.[26] Has the trajectory changed radically? If so, one should consider family or psychological stress, substance abuse, or depression as possible contributors.

TWO CONCRETE EXAMPLES

The RIME System

Considerations such as these formed the basis for an effort at the Uniformed Services University of the Health Sciences (USUHS) to improve the reliability, validity, usefulness, and feasibility of descriptive medical student evaluations by developing a standardized vocabulary for describing student progress. In this system, trainees progress through the stages of reporter, interpreter, manager, and educator (RIME).[27] A *reporter* has the interpersonal and clinical skills needed to obtain and present the history and physical examination. This is the level generally expected of students during their early clinical training. An *interpreter* can do this and can also prioritize and analyze patient problems most of the time. This might be a more advanced student or a typical intern. A *manager*, in addition to reporter and interpreter skills, demonstrates understanding and judgment about the disease process, pathophysiology, and patient preferences and manages the patient. This might be the level of an extremely strong student, but it is more typical of an early senior resident. Finally, an *educator* consistently knows the current medical evidence and is able to apply it critically and appropriately to specific patients. This is usually the level of a more experienced senior resident.

Faculty trained in this formal evaluation system exhibit high inter-observer correlation (0.8–0.83).[28,29] The RIME system has been validated against other measures. It identified 44% of students who failed the NBME subject examination, as compared to 19% for checklist descriptor rankings.[28] It was also more sensitive in predicting problems during internship (75% versus 8% for average clerkship grade)[30] and has been successfully transferred to other institutions.[31] While the particulars may be very different in veterinary education, the concept of standardizing descriptive evaluations may be useful.

The Script Concordance Test

As we have seen, expertise in clinical reasoning involves the creation of efficient knowledge structures, such as scripts, and the interaction between these scripts and specific case examples in memory. Thus, scripts become pre-stored knowledge structures whose individual elements have acceptable/not acceptable values and default values for missing information.[32] Medicine is an ill-defined domain with considerable uncertainty, and this makes assessment difficult, because scripts and case experiences are idiosyncratic. The script concordance test (SCT) approach is an ingenious assessment method for addressing these problems (see Figure 2).

Each section presents a brief and incomplete lead-in vignette based on an authentic clinical situation, followed by two to four test items. Each test item has three parts. The first part includes a diagnostic hypothesis. The second presents new information, such as a sign, a laboratory test, or an imaging study. In the third part, the learner records his or her answer on a five-point Likert-type scale from 'hypothesis is almost eliminated' to 'hypothesis is almost confirmed'.[33] Rather than giving credit for a single correct answer, the test weights each answer according to those selected by a reference group of teachers or experts. This aggregate scoring method better reflects the true variability of experts' reasoning paths.[34]

Early studies of the SCT method have shown that it eliminates the ''intermediate'' effect discussed above; that is, there is a continuous improvement in performance with greater experience and expertise.[35,36] One SCT was found to predict the scores of family medicine residents on their certifying examination two years later.[34] A secure online SCT has shown a reliability coefficient of 0.734 in students, chief residents, and board-certified urologists.[37]

CONCLUSIONS

Learners transition through a series of developmental stages in clinical reasoning as they progress from novice to expert. These different stages necessitate different educational processes and different methods of evaluating learners' competence. Attention to these stages has resulted in evaluation methods that outperform more traditional one-size-fits-all methods. The community of medical practice model is a simplified way to understand these developmental stages. While the model was developed in medical education, it has clear parallels to veterinary medical education, with the exception of the ''outsider'' level (because so few trainees participate in residency). The field of veterinary medicine will need to consider whether the problems associated with this developmental level are addressed by increased emphasis on post-graduate training, through professional organizations or alumni networks, or by some other means.

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AUTHOR INFORMATION

C. Scott Smith, MD, is Professor of Medicine and Adjunct Professor of Medical Education and Biomedical Informatics at the University of Washington; Director, Northwest Regional Faculty Development Center; and Acting Residency Program Director, VA Medical Center, 500 W. Fort St., Boise, ID 83702 USA. E-mail: scott.smith2@med.va.gov.